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PROSPECTS FOR DEVELOPMENT OF A U.S. HDTV INDUSTRY

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BEFORE THE

COMMITTEE ON GOVERNMENTAL AFFAIRS UNITED STATES SENATE

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CONTENTS

Page

Opening statements:
  Senator Glenn ... 1
  Senator Heinz ... 3

WITNESSES

Tuesday, August 1, 1989

Dr. Robert D. Reischauer, Director, Congressional Budget Office, accompanied by Dr. W. David Montgomery, Assistant Director, Natural Resources and Commerce Division, and Dr. Philip C. Webre, Principal Analyst, Natural Resources and Commerce Division ... 5
Juan A. Benitez, Deputy Assistant Secretary of Commerce for Science and Electronics ... 15
Dr. Craig Fields, Director, Defense Advanced Research Projects Agency ... 17
Tom Long, vice president and general manager, Technology Group, Textronix, Inc., representing the American Electronics Association, accompanied by Ms. Pat Hill Hubbard, vice president, education and science policy, American Electronics Association ... 26
Peter McCloskey, president, Electronic Industries Association ... 30
Dr. James J. Tietjen, president and chief operating officer, David Sarnoff, Research Center ... 33
Richard Jay Solomon, Media Laboratory and Advanced Television Research Program, Massachusetts Institute of Technology ... 36

Alphabetical List of Witnesses

Benitez, Juan A.:
  Testimony ... 15
  Prepared statement ... 95
Fields, Dr. Craig: Testimony ... 17
Hubbard, Ms. Pat Hill: Testimony ... 26
Long, Tom:
  Testimony ... 26
  Prepared statement with attachments ... 102
McCloskey, Peter:
  Testimony ... 30
  Prepared statement with attachments ... 146
Montgomery, Dr. W. David: Testimony ... 5
Reischauer, Dr. Robert D.:
  Testimony ... 5
  Prepared statement ... 47
  Responses to written questions ... 56
  "The Scope of the High-Definition Television Market and Its Implications for Competitiveness," staff working papers, July 1989 ... 61
Solomon, Richard Jay:
  Testimony ... 36
  Prepared statement with an attachment ... 247
Tietjen, Dr. James:
  Testimony ... 33
  Prepared statement ... 242
Webre, Dr. Philip C.: Testimony ... 5

APPENDIX

Page

Prepared statements of witnesses in order of appearance 47

"Beating Ourselves at the Game," book review by Alice Kessler-Harris, of "Made in America: Regaining the Productive Edge," by Michael L. Dertouzos, Richard K. Lester, Robert M. Solow and the Massachusetts Institute of Technology Commission on Industrial Productivity 257

"Toward a New Industrial America," by Suzanne Berger, Michael L. Dertouzos, Richard K. Lester, Robert M. Solow, and Lester C. Thurow, June 1989, Scientific American 259

"Workshop on Creation of Government/Industry Partnerships Through the Formation of American Technology Corporations," February 13-14, 1989, National Research Council, Washington, DC 268

"Origins of RCA," by Richard J. Solomon, MIT, February 1989 298

"High Definition Television [HDTV]: Economic Analysis of Impact," working document prepared by ATV Task Force Economic Impact Team, American Electronics Association, November 1988 300

"Television Manufacturing in United States: Economic Contributions—Past, Present, and Future," prepared for the Electronic Industries Association by Robert R. Nathan Associates, Inc., February 1989 340

"Economic Potential of Advanced Television Products," report by Larry F. Darby, Darby Associates for National Telecommunications and Information Administration, April 7, 1988 433

Letters and statements from:

- Dr. Kenneth Flamm, senior fellow, The Brookings Institution 495
- David H. Staelin, Massachusetts Institute of Technology 509
- Dr. Peter S. Friedman, executive vice president, Photonics 513
- Barry Whalen, Ph.D., senior vice president for plans and programs, and Mark Eaton, director, international programs, MCC (Microlectronics and Computer Technology Corp.) 516
- Semiconductor Equipment and Materials International [SEMI] 526

PROSPECTS FOR DEVELOPMENT OF A U.S. HDTV INDUSTRY

TUESDAY, AUGUST 1, 1989

U.S. SENATE,
COMMITTEE ON GOVERNMENTAL AFFAIRS,
Washington, DC.

The Committee met, pursuant to notice, at 9:35 a.m., in room SD-342, Dirksen Senate Office Building, Hon. John Glenn, Chairman of the Committee, presiding.

Present: Senators Glenn and Heinz.

OPENING STATEMENT OF CHAIRMAN GLENN

Chairman GLENN. The hearing will be in order.

Today the Committee turns its attention once again to the issue of U.S. trade and technology policy. That is a topic on which this Committee held 7 days of hearings in the last Congress. Our focus this morning is on high definition TV, HDTV, as it is called.

The Congressional Budget Office, CBO, will release at this hearing a report on HDTV requested by this Committee. This is not an all-inclusive study. The report is one part of a longer term CBO study still in progress on R&D consortia requested jointly by this Committee and the Senate Budget Committee, which is chaired by my distinguished colleague, Senator Jim Sasser, who also sits on this Committee.

Many of us in Congress are tired of, indeed we are alarmed by, increasingly seeing new products invented here in the United States, being perfected into mass produced consumer goods abroad, and then being sold back to us. I fervently believe that we need to preempt our foreign competitors from gaining the ability to do this. That is, we need to organize and position ourselves to be able to seize the advantage first.

It is not that our economic rivals are evil; they are doing what any good competitor would do. Simply put, they are taking advantage of a market opportunity before we do. Thus, the blame is not as much on them as it is on us.

I hope HDTV does not turn out to be another case in point. HDTV may be one of the most, if not the most, crucial technological advancements the U.S. electronics industry will have to wrestle with during the upcoming decade just before we enter the 21st century. It goes far beyond being just a prettier TV picture. HDTV has far more implications than that.

Because of the overwhelming size of the electronics sector in the U.S. economy, how HDTV develops could have an enormous impact on the Nation's future balance of trade. Because of the importance of HDTV technology in military applications, our national security may also be affected.

For all of these reasons I am very concerned about the role of our electronics industry in developing HDTV, which to me means more than just household television sets. I strongly support the Federal Government fostering HDTV investment by the private sector, and I strongly believe that Government must play a role, particularly with respect to research and development.

Indeed, I co-sponsored an amendment to the FY 1990 Defense Authorization Bill last week on the Senate Floor that would have reduced SDI spending somewhat, and one of the uses of the money saved would have been to increase DARPA's funding for HDTV to $50 million, which I viewed as seed money at this early stage. Unfortunately, that SDI reduction amendment failed.

While I am convinced we must move quickly to define a national strategy for HDTV, I also believe we must proceed in a deliberate fashion. That is why the CBO was asked to write a report for the Committee. They were asked to do an economic appraisal. This was not to be a full-blown economic-engineering analysis. And, since HDTV technology is still rapidly developing, you might say that CBO was shooting at a moving target in their assessment.

I am quite aware, courtesy of last Friday's Washington Post article on a leaked preliminary draft of the CBO report, that CBO's analysis is highly controversial. My hope is that CBO's presentation this morning, along with the reactions by the other witnesses, will serve a very useful purpose in galvanizing the public debate about the importance of HDTV, especially for those of us who care deeply about developing a more visible and unified Federal technology policy. As many of you know, my desire to create a new technology agency that would be a bona fide civilian counterpart to DARPA as part of such a policy is no secret.

So in my view, airing this debate is absolutely critical. We need to allay the fears of those in some quarters who claim that initiatives like HDTV will degenerate into pork barrel politics and who believe, in general, that Government has no direct role to play in fostering greater investment in the application and development of advances in civilian technology.

Clearly, U.S. industry is interested in pushing for HDTV, as evidenced by the amount of investment already taking place and by the investment planned for the future. The Bush Administration is also pushing for HDTV. However, to date the lion's share of the Administration's effort is coming through the Pentagon, which makes me particularly eager to hear this morning what are the Department of Commerce's plans. Finally, the money being invested by both foreign Governments and foreign firms speaks to the promise of the HDTV market.

I suspect that the exchange of views in this morning's hearing will intensify the debate about the extent to which these various pushes for HDTV are in fact good bets to make.

We have three panels of very distinguished witnesses before the Committee this morning and I am very anxious to hear their testimony. Before we do that, I will turn to Senator Heinz for any opening remarks.

OPENING STATEMENT OF SENATOR HEINZ

Senator **Heinz**. Thank you very much. First let me commend you on holding this hearing. I must say I am very impressed with the number and quality of the witnesses who are going to give us their time this morning to help us with what I think is a very important issue. I cannot help but reflect that years ago when our forefathers were placed in a difficult situation, they used ingenuity and common sense to find a way of working things out.

Today I suspect we will have to use those same old Yankee ingenuity talents to solve the HDTV quandary. And I say that because I suspect that if we do nothing, the Japanese and the Europeans, who have aggressive programs, are going to gain a near monopoly in HDTV and related systems, and the supporting technologies, everything from new type screen technology to semiconductors, to various other integrating systems.

And on the other hand, if we intervene in the wrong way, we will upset our own notion of the level playing field on which we all compete equally. We will have to find a new way to deal with this issue in a manner that is consistent with our free market principles, but yet make sure that we are not closed out of the sector by other nations' restrictive practices.

If there is going to be an American HDTV industry, I think it has some very high obstacles to surmount. I suppose the most important of those would be the advanced state of our competitors. I was in Japan earlier this year and saw what they are doing on HDTV. The Japanese Government has put over $100 million into their HDTV industry, and that long term investment is about to pay off. The Japanese system is scheduled to go on air as a regular matter in 1990. They have already broadcast via satellite.

The Europeans also are very advanced relative to us in the development of HDTV. They have simply decided that they are not going to allow the Japanese system in the EC. They have created their own standards and have put millions of their own into their project.

It is a combination of all these circumstances which understandably make American business reluctant to invest large sums of time and money in HDTV. And if you were they, why would you? It is going to be much easier for one of our companies to adapt the system to meet regulations than it is to create a whole technology. So why not just sit back, wait, let the other people do the work—they are getting Government money—and if you look at the EC, it is easy to see what is happening there.

It was begun in 1986 fully supported by a number of European nations. There was an understanding that was equally important, and that is that they would be totally protected from the Japanese. And since we were not doing anything, they did not have to worry, as usual, about us. And even with that protected, stable environment, it will be at least 3 more years until the Europeans get anything into service.

So where does that leave an American company? It leaves an American company facing an extraordinarily difficult set of circumstances. We are unlikely to be able to penetrate the Japanese market. That will be the day. The Europeans are pretty frank, they do not want anybody else in there either.

The Japanese, of course, are actively lobbying us to approve their standard so that they can get into our market. Our Government has a demonstrated track record of inability to protect our market against predatory practices. Dumping of TV sets is a good case in point. Dumping of semiconductors is the most recent, where we do not even do a good job of policing the agreement we have got. And so we have a great track record of doing nothing.

For example, and hypothetically, AT&T and General Electric, which have the VCR and TV industry to look upon as precedent, why would they put much money into HDTV? And the answer is, unless I miss my guess, they are not going to.

Now, CBO, which has done the study may disagree, but I am among the growing number of people like Senator Glenn who believe that HDTV is indeed a critical technology and a critical industry, that its ultimate version represents a synthesis of time, information, and communication. I will not get into a flight of fantasy and prophesy that within 10 years everybody is going to have a briefcase—a long briefcase maybe—that is an HDTV portable computer, et cetera, et cetera.

But I think we ought to remember that in the 1960s the idea of having a portable computer at a time when an adding machine weighed like 20 bricks, was something, to say the least, fanciful, and now many businessmen are taking with them on trips and working on the plane on something much more powerful than the Apple that I originally bought some 7 or 8 years ago.

Mr. Chairman, I will conclude. I just think our challenge is translating expectations into realities in the face of another reality, a severely weakened American electronics industry in which product after product, most notably TVs and VCRs, which are products we have created and which are technologies others, particularly the Japanese, have dominated. The result is an industry that is treading water. And I am not taking any bets on how long it can keep from drowning, because it is consumer product sales that provide funds for investment in R&D, and it is viable consumer products that attract investors.

So if we are going to have an electronics industry in this country, then we have to have a real presence. And right now in the consumer electronics business, we do not have it. So we have a lot to discuss today and I join you, Mr. Chairman, in greeting our distinguished panelists.

Chairman GLENN. Thank you very much, Senator Heinz.

Our first witness this morning is Dr. Robert Reischauer, Director, CBO, accompanied by Dr. David Montgomery, Assistant Director, Natural Resources and Commerce Division of CBO and Dr. Philip C. Webre, Principal Analyst, Natural Resources and Commerce Division of CBO.

Dr. Reischauer, if you will lead off, we would appreciate it.

TESTIMONY OF DR. ROBERT D. REISCHAUER, DIRECTOR, CONGRESSIONAL BUDGET OFFICE,[1] ACCOMPANIED BY DR. W. DAVID MONTGOMERY, ASSISTANT DIRECTOR, NATURAL RESOURCES AND COMMERCE DIVISION, AND DR. PHILIP C. WEBRE, PRINCIPAL ANALYST, NATURAL RESOURCES AND COMMERCE DIVISION

Dr. **Reischauer**. Mr. Chairman and Senator Heinz, we appreciate the opportunity to appear before this Committee. I will take this occasion to summarize the results of CBO's analysis of the private forecast of the markets for high definition television. This analysis that we are releasing today is, as you noted, an interim product that is part of a broader study of proposed industry research consortia. As such, its scope is limited to an examination of the economic assumptions that underlie the private market forecast for HDTV.

Proposals calling for Federal support to increase the rate at which U.S. firms bring new technology to market have been prompted largely by concerns about the competitiveness of U.S. industry. Proponents of such incentives argue that certain industries are at a disadvantage relative to industries in other countries, because our Government does not provide much support for technologies that are near commercial development.

One product that has been put forward as a candidate for such support is HDTV. Advocates of providing support for HDTV argue that it will represent the next major successful consumer electronics product. They believe that a U.S.-based HDTV industry could affect the future competitiveness of the entire U.S. electronics sector through its development of advanced technology and its use of manufactured inputs such as semiconductors, computers, and flat-panel displays.

To shed light on these issues, CBO's interim report sought answers to two related questions: Will there be a large market for HDTV receivers? Could this market be crucial to the competitiveness of the U.S. electronics sector?

With respect to the first question, CBO's analysis of the three available private market forecasts concluded that they represented the high end of the range of the industry's likely sales. Of course, no one can foresee with great confidence how successful HDTV will be. The success predicted by private market forecasts may be justified by the large price differentials that consumers have been willing to pay in the past for color over monochrome television and by the recent rapid growth in the market for premium television receivers.

However, we could discover that consumers do not value the incremental benefits of HDTV very highly, especially if there are cheaper types of advanced televisions from which they might choose.

The pace at which the HDTV market develops, as well as its size, is also open to question. As has been the case with other high-technology consumer products, such as video cassette recorders (VCRs) and microwave ovens, the introduction of HDTV will probably be followed by a lengthy period during which consumers, producers, and providers of ancillary services grope toward the definition of the product. This suggests that the market forecasts reviewed in the CBO report, which expect HDTV to be successful from the very start, may be too optimistic with respect to the timing of the development of this market.

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[1] See p. 47 for Dr. Reischauer's prepared statement.

Even if the optimistic forecasts of HDTV are realized, the question remains whether HDTV is likely to play a crucial role in determining the future competitiveness of the U.S. electronics sector. After evaluating the claims made regarding the impact of HDTV on competitiveness, CBO concluded that either the HDTV markets are unlikely to be big enough to have the hoped for effects, or the sequence of events asserted by the studies is not sufficiently developed to warrant the conclusions that have been drawn.

Even the optimistic forecasts of the potential size of the HDTV market are small relative to other markets in the electronics sector. The projected world market for HDTVs and related VCRs is forecast to be less than $30 billion—in 1988 dollars—by the year 2010. Last year the world market for electronic equipment reached $461 billion, and it grew by some $54 billion during 1988.

It seems implausible to suggest that such a small and uncertain future market will be more important as a driver of technology, as a provider of economies of scale, or as a determiner of competitive success than will be the growth of present markets, which are assured and are in existence now.

U.S.-based electronics manufacturing firms already have many incentives to maintain their competitiveness, and a large enough market in which they can enjoy economies of scale. Thus it is hard to believe that HDTV will, by itself, play a pivotal role in the competitiveness and technological development of the electronics sector as a whole.

Advocates make the case that HDTV will improve the competitiveness of the electronics sector because HDTV technologies will serve as technology drivers for the rest of the electronics sector. They argue that a network of common technology and components will make the knowledge gained in HDTV useful in other major electronic goods.

While this may be true, little concrete evidence has been marshaled to support this claim. Simply stating that HDTV will contain high technology components is not enough. Outside of display and imaging technology, HDTV technology is not unique. For example, the memory chips in HDTV are widely used in other products today, so the contribution of HDTV to that market is likely to be marginal.

Even the display and imaging technology is not unique to HDTV receivers. Producers of computer workstations already use high-resolution displays. U.S. computer firms will continue their research and development (R&D) and other investments in an effort to advance their strong position in the market for advanced workstations and high resolution imaging. Thus it is not at all clear that HDTV will act to drive or significantly spur advances in this technology.

The conclusions reached by the CBO study do not necessarily mean that Federal support for HDTV development is without merit. Support for HDTV might be justified for reasons other than competitiveness in the electronics sector—for instance, national prestige, scientific advancement, or military applications. In addition, development of the HDTV market, although small on its own, might have a role to play in a broader strategy of Government involvement in the U.S. electronics sector, including attempts to create a U.S. industry that manufactures a whole range of consumer electronics.

Finally, to the extent that the effort to foster HDTV development comes from the laudable desire to reduce the trade deficit, the policy prescription may be misguided. The trade deficit exists not because the United States suffered a loss of technological leadership, but rather because the U.S. economy is saving too little and devoting too much of its resources to current consumption. If reducing the trade deficit is the paramount objective, there is a more direct solution—namely, increasing national saving by decreasing the budget deficit.

Let me conclude by noting that my remarks today are not meant to foreclose the possibility that greater public intervention to foster U.S. competitiveness may be warranted. However, the list of possible interventions is long, and Congress should weigh the alternatives rather than examine requests for support by this industry or that on a piecemeal basis.

Thank you.

Chairman **Glenn**. Thank you very much. You other gentlemen, Dr. Webre and Dr. Montgomery, do you have any statements? No, all right, fine. Thank you.

Dr. Reischauer, you note in your testimony that the CBO analysis began by asking whether the available evidence supported forecasts of a large market for HDTV receivers. Why was this definition of HDTV used as a starting point?

Dr. **Reischauer**. I think that was a definition that was primarily used in the studies that we examined.

Chairman **Glenn**. Do you think the use of that definition—just TV receivers—is responsible for driving your conclusions?

Dr. **Reischauer**. Yes, it is. One can speak about HDTV in various forms—as a TV receiver technology, which is what we focused on, or as a term that is used to encompass a broad array of developments expected in the communications realm in the next century. That broader use of the term might include lots of other components, many of which are not, strictly speaking, associated with television or even with consumer products, even.

Chairman **Glenn**. Had you defined HDTV differently, had you considered some of those other areas perhaps more broadly, do you believe your conclusions would have changed?

Dr. **Webre**. If we talked about all the advanced imaging technology that is currently developing in computers, we might have rendered a very different conclusion.

Chairman **Glenn**. Well, there are a number of different things that go into HDTV, of course, that make it more than just a new, more accurate picture on television than is normally considered when we talk about HDTV. You seem to define it more as a TV set.

In this regard, is your conclusion about the uncertainty of the success of HDTV restricted to the consumer television portion of the HDTV market?

Dr. **Reischauer**. I think largely it is. What we were trying to point out is that advances in high resolution imaging are occurring in the computer market and elsewhere on their own. They are going ahead full steam. The question raised by these studies is whether there should be an additional push, an additional effort with respect to a consumer product.

Chairman **Glenn**. You are saying, then, that HDTV will not necessarily drive the computer market of the future because that is occurring with PCs and other things. But I think proponents of HDTV feel that HDTV becomes sort of the home engineering workstation, if you will, of the future. It combines all these things in one package.

Do you feel that HDTV will drive the computer market of the future?

Dr. **Reischauer**. No, we do not. But I think David wants to add something.

Chairman **Glenn**. Dr. Montgomery?

Dr. **Montgomery**. Thank you. Where we started was, as we were requested, with the three projections of the market for HDTV. As you picked up in your first question, those forecasts concentrated on the development of a consumer electronics market for television receivers and went from there to describe a number of alleged consequences for the rest of the electronics sector. These consequences were predicated on the assumption that if the U.S. industry did not produce this particular consumer electronics good, it would lose its leadership in a wide range of other areas and would lose the market for selling semiconductors and many, many other things.

We could not find in the studies that we examined, or in our further discussions any evidence which described what those linkages were, how those connections would occur, or what difference it would make to the rest of the electronics market if the United States did not produce these particular consumer products. And that was kind of what led us to our conclusion that we could not see, based on what has been described so far, how this consumer technology could drive the rest of the market, given the many other activities and types of technology that are already being developed.

Chairman **Glenn**. Well, it is unclear to me how your report accounts for these other beneficial spillovers that will occur. I'm sure other testimony this morning will go into considerable detail on those.

Your report does note that HDTVs are close to engineering workstations. I imagine they are at the leading edge of a host of technologies. Do you feel that these other technologies are going to develop into consumer electronics on their own, quite apart from HDTV, and so we do not really need HDTV?

Dr. **Montgomery**. No, sir. It appeared to us that these other technologies for advanced workstations and for displays that would be used for manufacturing are already in progress, and that the market for those goods—they would be sold to automobile manufacturers, or whatever—is separate from the consumer electronics market. We need to look at whether there are linkages, or economies of scale so that by producing consumer goods you would also be able to produce other types goods more cheaply.

We could not see that those linkages—that is, if you do not have HDTV, you would be unable to produce workstations—were there.

It appears right now that the industry is proceeding in the opposite direction—Philip can correct me if I am wrong. The industry is not only doing research on high resolution but is is also beginning to manufacture the workstations—and without a commitment to HDTV yet.

Chairman GLENN. Is that fair, Dr. Webre?

Dr. WEBRE. Yes. Sun, for instance, just announced it is going to be releasing a new workstation based on Texas Instruments semiconductors that will have roughly the same line density that people are talking about for HDTV. Similarly, IBM this year is expected to sell over 150,000 high-end display graphics boards that are, again, at the same resolution as people are talking about for HDTV.

The whole imaging market is developing much more quickly than we see HDTV developing. So the question is, which technology is going to push which? It is not that anyone is saying that nothing is going to come of HDTV. But they have not shown that the development of the consumer box will drive all these other technologies. And, in fact, there is a lot of prima facie evidence that these other developments are parallel to and, in many cases, occur before the development of a substantial consumer electronics market.

Chairman GLENN. Can you briefly describe the areas where you feel there will be strong, direct spillover benefits from HDTV?

Dr. WEBRE. People are talking about using flat-panel displays in many areas that are not necessarily HDTV. Already Senator Heinz referred to the laptop computer. Last year in the United States there were three-quarters of a million laptop computers sold, and that market is developing very rapidly and will continue to develop.

There is a substantial number of flat-panel personal television sets, which are non-HDTV television sets. I believe the Japanese are scheduled, or intend to sell something like 1 or 2 million of them this year. And now people are talking about using these same flat-panel displays in everything from automobile panels to jet plane panels. I believe that is what Dr. Fields wants to do with them. So all those uses of that flat-panel technology are coming about.

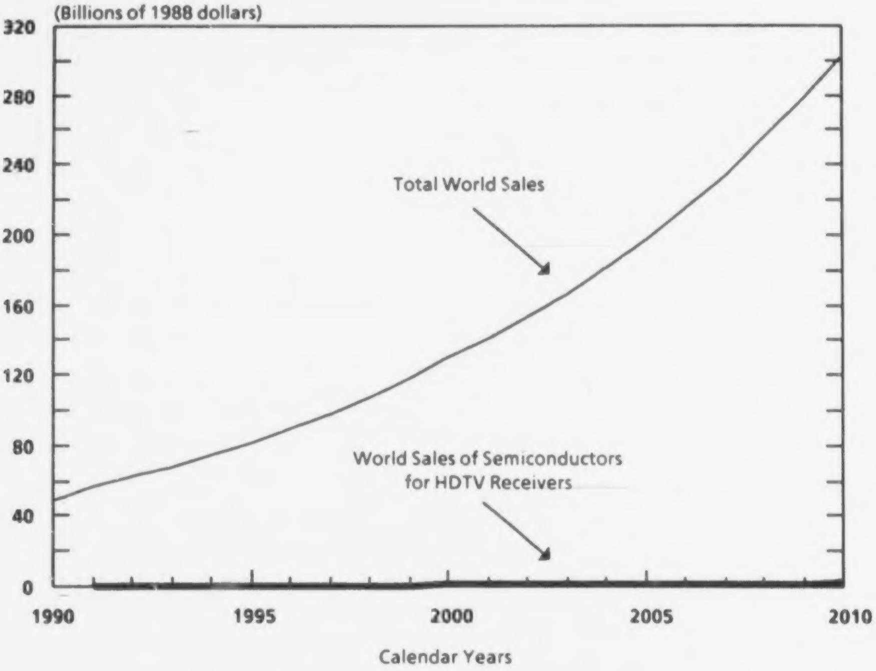
In addition, HDTV will use some specialized kinds of semiconductor technology, known as called digital signal processors (DSPs). It is a small semiconductor market, about $500 million, currently dominated by American firms, and these DSPs for HDTV would be at the low end of that market, typically. And, as we noted in our report, this is one specific case in this one area of semiconductors where there might be a substantial impact.

In addition, there are specialized semiconductors that drive the displays—it is a specialized market that does not clearly carry over.

But in terms of the overall influence of technology, we would like to show you a graph. The graph shows that, as Dr. Reischauer noted, the overall electronics sector is much bigger than the HDTV market. And similarly, if you look at semiconductors alone, in the aggregate and outside of these little specialized markets, HDTV sales—HD semiconductor sales—are only a small fraction of that total market, and, in fact, a decreasing fraction.

[The graph referred to follows:]

AEA Forecast of World Sales of Semiconductors



SOURCE: Congressional Budget Office using data from American Electronics Association, "High Definition Television (HDTV): Economic Analysis of Impact" (prepared by the ATV Task Force Economic Impact Team of the AEA, Santa Clara, Calif., November 1988)

NOTES: Assumes that semiconductor content of non-U.S. HDTV receivers is the same as that of U.S. receivers. Excludes HDTV video cassette recorders.

Dr. **Webre**. The red line does go up, by the way. It is really hard to see, but we made sure to indicate that we were not trying to show that these sales were stagnant.

Chairman **Glenn**. It is not exactly a quantum leap. [Laughter.] Is it your testimony that if there is not a large consumer market for HDTV, as TV alone, as its proponents claim, that all the other benefits of HDTV, the revival of U.S. competitiveness in semiconductors, maintenance of our lead in personal computers and so on, are unlikely to occur?

Dr. **Reischauer**. We are not arguing that the market forecasts that we reviewed are out of bounds at all. We are pointing out that these forecasts are at the high end of the likely markets, that they presume consumer acceptance, and that they presume that this is a highly successful consumer product, as successful as any of the most successful recent products that we have had. I do not want you to think that we are saying that there is no way that the market in the first decade of the next century will be over 10 million units, let's say 10 to 20 million units. We are not saying that at all.

Chairman **Glenn**. Do you have any figures on how much it will cost the TV industry, the transmitting end of the industry, to adopt to HDTV? I haven't seen any good figures on that. I have read some trade press articles and I read some of the testimony of other witnesses that will follow you this morning and I did not really see any good estimates of what it is going to cost the industry to switch over.

Dr. **Webre**. I would ask that of Dr. Solomon. The MIT Media Lab has spent a lot of time thinking about this issue.

Chairman **Glenn**. Good, he will be on our third panel here. Dr. Solomon, you can get ready for that one.

I take it from your testimony, Dr. Reischauer, that you support DARPA's funding of flat-panel display and other high resolution digital imaging techniques, is that right?

Dr. **Reischauer**. Well, we certainly are not in the business of stamping a seal of approval on this expenditure or that expenditure by Federal agencies. I think we would not second guess DARPA's decision to allocate resources to those areas that it feels have important military applications.

Chairman **Glenn**. Well, let's say you would not be against that allocation of funds then. I will put it a different way.

Unfortunately, when we vote money here we do have to make that decision and so we look to people like you for advice on this matter, that is the reason I was asking the question.

You note in your testimony that your report does not address the question of whether and to what extent there should be Government involvement in the HDTV sector. Does this mean you believe that the benefits from Federal Government support of HDTV will not be sizable?

Dr. **Reischauer**. No, it means that there are broader sets of considerations that we intend to review in the full report that we provide you later this fall.

Chairman **Glenn**. What is your due date on that? Can you tell us when to expect that report?

Dr. **Webre**. Sometime in the late fall or early winter, I believe.

Chairman **Glenn**. What will it encompass? Will it be another economic analysis of HDTV or a broader look at the engineering as well as economic aspects of it? Will you do a cost analysis in that follow-on study also?

Dr. **Webre**. Well, my engineering degree expired long ago, so it is going to be more a straight economic analysis with professional questions of trade offs—is the DOD the most appropriate place to do this work, or is there a civilian agency needed for technology promotion—a lot of these kinds of questions with which this Committee has been grappling for the last couple of years.

Chairman **Glenn**. You note that the size of the HDTV market relative to the total consumer electronics market—one has to make that qualifier there—is small, and thus that HDTV may not have a significant impact on the demand for semiconductors. That is surely one way to view the issue.

I take it that an alternative but equally valid way to view the issue is to ask what percent of the semiconductor sales is accounted for by consumer electronics? I do not know the answer to that. If it is a relatively large percentage, it may well be that HDTV, if it takes off, will in fact increase the demand for semiconductors.

Do you know the percentage of semiconductor sales accounted for by consumer electronics?

Dr. **Webre**. The last figures we saw, which were for 1987, show the share of semiconductor sales that goes into consumer products is about 30 percent worldwide. In the United States, it is about 15 percent; in Japan, it is about 40 percent.

Chairman **Glenn**. Okay. So that would mean if HDTV took off it would have a significant impact.

Dr. **Webre**. Well, these figures on the graph are not our figures. They are from one of the market forecasts that we analyzed. And if you take their estimate of the amount of semiconductors per HDTV receiver, and multiply it by the number of receivers they forecast to sell, then you get the lower red line. The high blue line is their forecast of total world semiconductor sales.

So as the percentage, even under their assumptions—this is not our scenario, this is the American Electronics Association's scenario—even under their scenario, it is a decreasing percentage of sales.

Dr. **Reischauer**. If consumer electronics continued to absorb something like 30 percent of the total semiconductor market, the numbers in this chart would suggest that only 3 percent of the consumer electronics market would be semiconductors for HDTV, so that it would be a very small share of even the consumer market in the future.

Chairman **Glenn**. Let me make sure I understood your answer to an earlier question. Your study later this fall—and we will certainly look forward to that—it will not get into more of the engineering aspects of HDTV, and possible applications, quite apart from just home TV viewing?

Dr. **Webre**. No, we are not engineers.

Dr. **Montgomery**. No, sir. The Office of Technology Assessment has been doing some work on HDTV, on some of the more technical aspects. In our division of labor with OTA, we concentrate on the economic cost and policy side, while they are working on the technological and engineering aspects. They have reviewed our drafts and we try to review theirs, but we would want to look at whatever evidence could be presented in an economic context about what these linkages mean in the market.

Chairman GLENN. Your report says that if there is an expansion in demand for semiconductors as a result of HDTV, it is likely that existing producers, largely foreign ones, will fill that demand. Are not there opportunities for new business entrants created by an expansion in demand, and would not this particularly be the case if existing semiconductor producers were at capacity?

Dr. REISCHAUER. I think what we are saying is not that foreign producers necessarily will dominate the sales in this area, but rather that there is no guarantee that a development of U.S. capacity in this area will be met by a demand from the U.S. industry, especially if we look at the behavior of American computer manufacturing firms, which have dominated computer manufacturing for a number of years. And yet when semiconductor fabrication in Japan and elsewhere became competitive and attractive from a price standpoint, American firms went abroad to find supplies. We would expect the same sorts of market pressures and market reactions to exist in the HDTV industry.

Chairman GLENN. You have testified that we have to build a Federal technology policy systematically. I agree with that. That is the reason I have been, for the past couple of years, pushing as hard as I can for the creation of an agency which would be, in effect, a civilian counterpart to DARPA.

DARPA has been preeminently successful in what they have done for the military, and a lot of civilian spinoffs from that, as Dr. Fields, I am sure, will testify a little bit later on today. And I have been a great admirer of that agency and followed what they have done very closely.

I also believe you are dead right about the importance of fixing our budget deficit; increasing savings; and so on. Regaining our international competitiveness will require pursuing, in addition to those things, formulating a new, strong technology policy. I think that is critical.

We need to get our budget in order as well as put together a coherent technology policy; that is, and do them together. Do you agree with that?

Dr. REISCHAUER. Well, certainly if a decision is made for the Government to increase its effort to spur technology development and manufacturing technology in the United States, we will have to have some coordination of it, or some creation of a new entity in the Government to make these decisions.

Chairman GLENN. What happens every time we get into a discussion like this is whether we are going to set industrial policy like some other nations, where we as Government pick the winners and losers, in effect. And you can get a good debate on that any day on any corner around here. It gets the temperature rising when you bring that up.

But we also know we are up against very tough competition, too, so I do not know how far we can go without some new policy initiatives.

Well, thank you. We have two other panels this morning. We will be hearing more, I am sure, about your report from these witnesses. We appreciate your efforts and appreciate your being here this morning. Thank you very much.

Our next panel, panel 2, is Mr. Juan Benitez, Deputy Assistant Secretary of Commerce for Science and Electronics, and Dr. Craig Fields, director of DARPA.

Mr. Benitez, if you would lead off, we would appreciate it.

TESTIMONY OF JUAN A. BENITEZ, DEPUTY ASSISTANT SECRETARY OF COMMERCE FOR SCIENCE AND ELECTRONICS [1]

Mr. BENITEZ. Mr. Chairman and members of the Committee, I am very honored to have the opportunity to discuss the scope of HDTV and the implications the development of HDTV and related technologies has to the competitive and economic position of the United States.

Mr. Chairman, having spent all of my professional life in the private sector, as both an engineer and a businessman, with the last 11 years in the semiconductor industry, I find it very challenging and stimulating to have been asked to analyze the economic opportunities presented by HDTV.

I can also appreciate the operating importance of creating new markets to maintain pace with growth, especially in the electronics industry, where product life is short, development times are becoming longer, and continuous capital needs are paramount.

It is important to qualify what HDTV represents. HDTV is more than a single new consumer electronics breakthrough. It is not even a single technology. Rather it is an important new application, or set of applications, of several evolving technologies and markets such as semiconductor memory, digital processors, flat-panel displays, fiber optics, and integrated services digital networks.

Advances in these technologies or markets for HDTV would in turn apply to advanced computers, industrial imaging, medical diagnostics, robotics, factory automation, defense displays, and information systems and networks. In other words, advanced television should be viewed as a natural progression of computers and advanced information systems.

By stressing that HDTV is more than a single technology, I do not mean to minimize the significance of HDTV as a breakthrough in home entertainment, nor should we minimize the importance of the consumer electronics market. However, we should emphasize that HDTV will provide the linkage to several interrelated and user markets.

Since HDTV is highly semiconductor intensive, it carries special promise for the U.S. semiconductor industry. Advanced TV applications make heavy use of memory chips, digital signal processors, converters and other microprocessors. For example, it is estimated that an HDTV set will use up to 50 megabytes of memory, which is approximately 50 times the capacity used in one of today's personal computers. This market could provide the critical mass of demand needed to invigorate the U.S. semiconductor industry and to achieve important economies of scale. This, in turn, could allow industry to generate the large and continuous capital needs that are inherent of the semiconductor industry.

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[1] See p. 95 for Mr Benitez' prepared statement.

In view of the overwhelming importance of electronics and computers to industry and the military, as well as to consumers, significant U.S. participation in HDTV can enhance the economic linkage between the U.S. electronics industry and the U.S. competitive position overall.

Mr. Chairman, I would like to discuss some of the Administration's initiatives that can help foster U.S. participation in developing HDTV and products using other emerging technologies. President Bush has recommended to Congress that the capital gains tax be reduced and that the Research and Experimentation Tax Credit be improved and made permanent. These measures will provide added incentives for the long-term commitment of resources to technology development and improvements in manufacturing.

The Administration is also considering options to clarify the effect of U.S. antitrust laws and industry joint ventures. The Commerce Department believes that there is a direct link between antitrust clarification for joint ventures and American firms' abilities to compete globally in high technology markets. Secretary Mosbacher recently testified on this issue before the Subcommittee on Economic and Commercial Law of the House Committee on the Judiciary.

Also, the Administration is studying programs aimed at developing broadcast and transmission standards that should enhance the timing and overall strategy for HDTV.

I should also indicate that Commerce is working with other agencies to develop further recommendations that are commensurate with the technical complexity, economic magnitude and strategic implications that HDTV has. The Administration's activities to date have helped make both Government and the private sector more aware of the potential importance to our economy of U.S. participation in HDTV development and we will continue to consult with the private sector to better understand our capabilities in this area.

Turning to the Congressional Budget Office report, I want to emphasize that we do not share its general pessimism about the promise of HDTV. On the other hand, both views must be somewhat speculative at this time, since no one really knows how large the ultimate HDTV market will be.

However, I would like to note that the report is inaccurate in some areas. Because of my business experience in the semiconductor industry, I will focus on this aspect of the report. On page 3 of its Executive Summary, the report states broadly, "Even if domestic firms become the dominant suppliers of HDTV sets, some components, semiconductors in particular, probably would be imported."

This suggests that the majority of semiconductor chips in sets made by U.S.-owned HDTV producers would likely be produced by foreign firms. I find this very unlikely. The only support given for this suggestion is the statement that although U.S. firms dominate the personal computer market, they buy many of their semiconductors from abroad. In fact, Mr. Chairman, our semiconductor manufacturers maintain a very strong competitive position in supplying

U.S. computer manufacturers; 40 percent of total U.S. semiconductor production goes into computers.

Compare this to the consumer electronics market, which is dominated by foreign companies who manufacture primarily in the United States. Their purchases of U.S. semiconductors represent only 7 percent of U.S. semiconductor sales. We conclude that U.S. participation in HDTV would yield substantial gains in U.S. semiconductor sales.

Also, the report implies that the problem with the U.S. DRAM sales during the 1980s resulted from a decrease in demand. The report failed to mention Japanese dumping of DRAMs, which drove all but one domestic producer out of this business, and I can testify to that because the one domestic producer left was the company for which I worked prior to joining the public sector.

In summary, I wish to contrast the thrust of this report, which downplays the commercial importance of HDTV, with the tangible commitment of the Japanese in this area. Their Government and electronics industries have made vast capital investments in this field, estimated in the billions of dollars already. Given the impressive record of the Japanese in selecting promising technologies for commercial development, it may not be prudent to underestimate the promise of HDTV.

Thank you, Mr. Chairman and members of the Committee for this opportunity. The Commerce Department and the Administration will work with Congress as we believe we share the same objectives and wish to achieve the same results.

Chairman GLENN. Fine, thank you, Mr. Benitez.

Dr. Craig Fields, head of DARPA.

TESTIMONY OF DR. CRAIG FIELDS, DIRECTOR, DEFENSE ADVANCED RESEARCH PROJECTS AGENCY

Dr. FIELDS. Mr. Chairman, thank you for the invitation to come today. As you indicated in your opening remarks, it is a little peculiar for a witness from the Defense Department to be commenting on this issue associated with international trade and home entertainment because some of the countries, most of the countries involved, like Japan and Germany, are not military adversaries and DOD is not in the entertainment products business, at least not on purpose. [Laughter.] But I am pleased to come and——

Chairman GLENN. Have you been over listening to the debate on the floor in the last couple of days?

Dr. FIELDS. Yes. I am actually pleased to make some comments. I do not want to get into what I would call a detailed criticism of CBO's unique position as expressed in their report because I think others have said things about it and will say things about it on a sort of point by point basis.

But I do want to use the occasion of the release of this report, which I think does stir public debate and discussion in a healthy way, to try to use it to clarify some of the issues. And in particular, the question I would like to face with you today in a generic but specific way is the following. Why is it that I have this CBO report, which basically says that HDTV is not all that important, on one hand, and then I have these reports that say that HDTV is very important from a variety of sources, from the Semiconductor Industry Association, from the Satellite Broadcasting and Communications Association, National Cable Television Association, the National Association of Broadcasters, the American Electronics Association, the IEEE, the EIA, the Semiconductor Equipment Manufacturers Association.

Then turning to private firms, domestic firms, Phillips, Corporation for Public Broadcasting, CBS, Capitol Cities, ABC, NBC, David Sarnoff and Thompson, you will have a witness from David Sarnoff later, Digital Equipment Corporation, Zenith, Belcor, GTE, Texas Instruments.

And then to show this is not only on the business side, AFL-CIO, an organization called Labor Industry Coalition for International Trade, which I am going to be speaking at in a few days. And that is rather interesting, because it includes the United Paperworkers International and Oil, Chemical and Atomic Workers International, and so on, to show that this is a broader issue.

And another association of labor unions—and I could read some of those—United Electrical Workers, United Furniture Workers of America, and so on. As well as universities, MIT, New York Institute of Technology.

Well, what is going on abroad and what is the position there? I can only read the title of the CIA report, "Foreign Firms Poised to Commercialize High Definition Television," but if you have not read that report, I would suggest that you do so.

Another report, which is unclassified, from the Foreign Broadcast Information Service—one of the more efficient parts of the Government that collects open source information world-wide—on HDTV, which talks about the activities in France and Germany, in the European community, in Japan and Korea, in Italy and China and the Soviet Union and a number of other places.

And then, of course, we just sent a study team to Japan and they were as impressed as Senator Heinz with the situation there. They brought back product literature and, in fact, wanted to buy some things: a Toshiba 55-inch television, a Toshiba—if that is not big enough—110-inch television, Toshiba studio equipment, recorders, and news encoders. Mitsubishi products, which are sort of interesting, go up to 200 inches. Hitachi projection systems, Hitachi rear projection systems.

And the interesting thing about this product literature is that they talk about applications in airport information systems and in showrooms and power supply stations and traffic control and teleconferencing, and in education and training and in catcam and in production control systems, visual display, medical diagnosis, museums and art galleries.

And Panasonic equipment. Just indulge me a moment more. Nikon Electric HDTV equipment. Nikon, Ikangami cameras, Canon cameras—these are for sale. Hitachi. This Hitachi catalogue is sort of interesting because what they are talking about is the production technology in their factories, which they are so proud of, for HDTV products, plural.

Panasonic, Canon—and this Canon product, incidentally, is for home electronic photography—and I will get back to that in a moment—not for consumer television.

Sony digital encoders, Sony displays like those that were purchased by the FAA recently. Sony video projectors, NHK, getting into the broadcast action business, and even brochures from two art galleries, a high definition gallery and a high vision gallery using HDTV.

And then, of course, we can turn to the Electronics Industry Association of Japan, November 1988, and their statements on the Japanese investment. In this recent newspaper article from Japan Industrial Daily, July 6, 1989, about the increasing dominance and entry of home consumer manufacturers into the DRAM business.

And then one of the sources that was not considered by CBO, namely the Ministry of Post and Telecommunications and their study of the future, said 14.5 trillion yen related sales to HDTV to the year 2000, and you can use whatever exchange rate you want in order to convert 14.5 trillion yen into dollars.

So we got the CBO report, and now we have got these other things. [Laughter.]

Chairman GLENN. Outside of that, do the Japanese have an interest it? [Laughter.]

Dr. FIELDS. And I might add that I brought about a third of what we have, because it was just too much. But the fact is there is an interesting and important lesson to be learned here, and you started talking about that lesson and I want to expand on it, because I think there is a good reason why we have these two positions.

One is the question of what you mean by HDTV. According to CBO, what they mean by it is the television in the living room, and I will accept that that was the definition that they chose to use. I think what most people mean when they talk about HDTV is a broader range of things, and just let me explore that just for a minute.

I think people see not only television, HDTV and also IDTV and EDTV, but also VCRs and camcorders and electronic photography, and home fax machines and home copiers and a whole range of products. And then the underlying technology components, pervasive components that are common among those, and things like flat-panel displays, solid state projection displays, laser printers and scanners, high-density magnetic recording heads, the mechanical tape and disc handling equipment, signal processing chips, memory chips and so on.

And then some of the special tools and materials like lithography equipment to make those. And then going back downstream saying with those same components the industrial things. And then publishing, and film making, movie theaters and catcam, military and medical, and so on. So I think one of the two reasons there may be this difference of view is just what do you mean by HDTV. Do you take the narrowest possible view or a broader view?

And the second issue is that CBO testified that they took what I will term a purely economic approach to this, rather than an engineering-technical approach because of their staff capabilities. And, in fact, it is worth going beyond the numbers a little bit to talk about what those numbers mean technically.

I would recommend for your attention the study that was done by the MIT Commission on Industrial Productivity called "Made in America," in that study they investigated consumer electronics and came to the conclusion, several places in the report, that consumer electronics is important above and beyond the dollar value of the products in consumer electronics because it is such an important driver for things like semiconductors and robotics.

And there is an appendix that people have not read—although I wish they would—which goes into consumer electronics, again from the MIT study, much more deeply. And because I have taken so much time, I am not going to read the quotes. But lest you think the Japanese feel differently about this, I will read a snatch from Akiro Morito's book, "A Japan That Can Say Know," in which they talk about the fact that, in fact, you cannot have a semiconductor market without mass production. And they are saying "rice cookers and other household appliances" are some of the mass production end-use products that would be useful in consumer electronics.

Also, you have to look beyond the numbers to what kind of chips are involved, how many chips and so on, rather than just looking at the dollar value, because a lot of the chips in HDTV are inexpensive, like DRAMs. And DRAMs are a technology driver and an important one.

And I would, again, commend for your attention a book called "The Microelectronics Race: the Impact of Government Policy on International Competition." It is probably one of the best books around on the subject. And they go on at great length about why DRAMs are important and, again, in the interest of time, I will not read the quote, but just comment that the central issue is that typically, DRAMs are used as a technology driver, which means that the technology in DRAMs are 18 to 24 months ahead of other technology in other chips. That means that manufacturing and production lines are refined by using DRAMs, and you refine the production lines by large volume production.

You can find out what is wrong and get it better and better to get the yield. People stay in the DRAM business just to do that, even if it is not very profitable. In fact, one company decided to get out of the DRAM business a few years ago. Soon thereafter they found that they had to invent a test chip with no particular function whatsoever to run through their production line to refine the manufacturing which, when they looked at it, was very much like a DRAM chip except they could not sell it because it did not do anything useful.

And so there is real value in looking at the particular chips and the number of chips rather than dollar value of chips in HDTV. And I am sure Juan will back this up from his personal experience in industry.

So I think those are the two reasons—namely, number 1, what is HDTV; and number 2, go beyond the dollar value to the technology in HDTV—that really are the basis for the difference of views. But it is also a basis for trying to understand a little about what we might do about it because I think that the focus here has to be on the broad infrastructure issues, technology based infrastructures, and not just on sort of a plastic, woodgrain box that shows TV in the living room.

There have been a number of newspaper stories lately that I want to remind you of. There are the stories about ETA leaving the supercomputer business, and anxiety about whether Cray, the remaining supercomputer manufacturer, could stay in the business; newspaper stories about Monsanto being sold to a foreign investor as one of the last—almost the last—remaining wafer producers in the United States; articles about Sematech; articles a few years ago about the Microelectronics and Computer Technology Corporation in Austin, Texas, starting up; about Perkin-Elmer leaving the semiconductor equipment business, lithography business; about the attempts, which I hope will succeed, for U.S. memories.

What I am tying to say is all of these are the same problem, the same thing, and in talking about HDTV we are trying to deal with more of a pervasive underlying problem.

Thank you very much.

Chairman GLENN. Thank you, both of you.

Let me follow up, Dr. Fields, on this. I think what CBO indicated a little while ago—and this may be a valid point, I do not know, I have not made up my own mind yet—but are there other and cheaper ways to get all these capabilities you are talking about without going to HDTV?

In other words, are there other routes to get the engineering home workstations, to the advanced personal computer, and all the things that can feed into those systems and expansion of them, as opposed to going through the HDTV route?

Dr. FIELDS. Well, the propositions that I have heard made by the AEA and by other sources to the Government for action on this, in fact, all deal with these underlying issues. And I do not think that there is a less expensive route. Remember, we are dealing with the underlying components, the manufacturing technology that not only make possible HDTV but also a variety of other things.

Also, realize that there are factors beyond the R&D. When I talked to American companies about why, with billions in investment abroad, there is so little investment here, they cited a number of reasons of which R&D investment is only one. Concerns about antitrust, anti-dumping, opening foreign markets, issues associated with intellectual property protection abroad, and a variety of other things play a role, too, and they do not cost any money.

Chairman GLENN. Have you seen any figures on the cost of changing television stations, of what would be required to change our TV transmission system to HDTV?

Dr. FIELDS. I do not have those figures available.

Chairman GLENN. We were advised Mr. Solomon could give us those answers, so we will hold it for Mr. Solomon once again.

We are really looking forward to your testimony, Mr. Solomon. [Laughter.]

Mr. Benitez, last March, Secretary Mosbacher testified before Congressman Markey's Subcommittee on Telecommunications and Finance, and noted that he is chairing an Economic Policy Council working group on HDTV.

He indicated then that he thought the EPC's recommendation for a Federal HDTV policy would be completed by July. Last week Deputy Secretary Murrin testified before the Senate Commerce Committee and said the report would not be completed until December. We now hear it might be finished by fall.

What is Commerce's timeline for this? What is the reason for the delay?

Mr. BENITEZ. Well, Mr. Chairman, that is a very good question. We have asked the same question ourselves internally. All I can say is that we believe that HDTV, due to its complexity and magnitude, when you are evaluating both the economic and technological aspects of the project, require a much deeper evaluation and analysis, and we continue to pursue that route.

I can only say to you that we are targeting to complete those recommendations sometime toward the latter part of this year, but I do not have a specific date at this point.

Chairman GLENN. Has the HDTV Advisory Committee—I understand it is a committee comprised mainly of industry CEOs—been playing a role in this?

Mr. BENITEZ. Very much so, Mr. Chairman. Secretary Mosbacher meets with this Advisory Committee periodically and the main thrust in the agenda is to make recommendations to Secretary Mosbacher that better allows us to evaluate the parameters of the HDTV program.

Chairman GLENN. Dr. Fields, you have been mainly concerned in DARPA with defense applications of R&D, of course, although many of the things that DARPA deals with have major civilian, commercial impacts also.

What can you tell us about the military programs on HDTV that you are running—I know you cannot get into classified areas. Where do you see HDTV fitting into the military R&D picture?

Dr. FIELDS. Sure. Well, there are just so many places, and I will just give you a sampling. We are interested in, and pursuing, as was mentioned by CBO earlier, the installation of large flat-panel displays in cockpits of fighter planes to give much better information presentation to the pilots, and do it within the power budget and the volume budget that you can do in a fighter plane.

We are looking in the same way at putting flat-panel displays with battle management maps and overlays in tanks where you could not use any other technology realistically today.

We are looking at doing it as intelligence workstations where the main attribute is much, much lower cost, because we procure in such small volumes that if it is possible to get a mass produced item, it is really much better. So that lower cost will be important there. Again for lower cost, HDTV displays in shipboard command and control systems, stationary command and control systems like at SAC, and so on. Use for map displays in Army command centers where for the first time they will be able to see legibly whole map sheets with battlefield overlays. They just go everywhere.

Chairman GLENN. What kind of HDTV civilian spinoffs do you see at this point? I know you are always mindful of that as you develop things over at DARPA.

Dr. FIELDS. Well, again, it is almost impossible to think of places where this does not apply, because of the higher performance or the lower cost. What people are pursuing are publishing systems, medical display systems, catcam systems. We heard at a breakfast this morning about Ford Motor Company buying Japanese HDTV equipment for purposes of catcam for plant control systems so that you can see what is going on in the factory like at a nuclear power plant with a better display than you would have now. It goes on and on in terms of industrial applications.

Chairman **Glenn**. Coming back to CBO's position, even if we accept everything that you say about the potential for HDTV, we still have the problem of infrastructure development. We are left with the question of whether there will be a sufficient consumer market to provide the funds for that development. If such a market does not materialize in the U.S., what is the alternative? Would we just be pouring a lot of money down a rat-hole, or are we just assuming that this will automatically move into public acceptance and everybody will buy HDTVs, or will we really have wasted many billions of dollars?

Dr. **Fields**. Well, it seems to me that the investment notions that are on the table really are to invest in the components—manufacturing technology and the infrastructure—the common components in both the consumer products and the industrial products.

If it is the case, which I find extraordinarily unlikely, that the American public chooses not to buy this whole range of consumer products, unlike in Japan, the Far East and in Europe, the same components will find their way and will be in home computers—well, forget home computers because you do not want consumer products—workstations, engineering workstations and in all of the other industrial applications that I mentioned earlier. In fact, that may be the earlier applications for the technology. So I do not think it is throwing money down a rat-hole, as you might speculate.

Chairman **Glenn**. Mr. Benitez, what guidelines do you believe should be followed in the funding of HDTV R&D by the Federal Government? For instance, should we mandate that all publicly funded HDTV R&D be carried out strictly in this country?

Mr. **Benitez**. Well, Mr. Chairman, Secretary Mosbacher has on several occasions mentioned a position that I firmly agree and believe in, and that is that any U.S. dollars committed and allocated for R&D, of course, should have the ultimate effect of positively impacting the U.S. consumer sector as well as the overall U.S. economy. So even though I am not directly opposing foreign participation in domestic R&D programs, I would make this generic recommendation that it have the ultimate effect of benefiting the U.S. consumer sector as well as the U.S. economy.

Chairman **Glenn**. For instance, should U.S. subsidiaries of foreign firms be excluded from receiving such funding?

Mr. **Benitez**. I would say, Mr. Chairman, that the position to be taken, specifically in that regard, should be a position of reciprocity and we should evaluate each particular situation on a case-by-case basis and based on reciprocity as it applies to that particular situation, then make that determination.

Chairman **Glenn**. Well, that is a major problem we have to face up to. I am just not sure how to do it. How can we ensure that a U.S. firm will not use public funds to perform its R&D on HDTV in subsidiaries abroad? Should we prohibit that by legislation when we provide the funds?

Mr. **Benitez**. I am not sure I have an answer to that question. I think that, again, the situation must be driven by the specific situation presented. I can say to you, if I could, Mr. Chairman, that we all have a personal interest in protection of intellectual property rights and technical information and properties that belong to the United States, but at this particular point all I would say to you, if I could, is that it is done on a case-by-case basis. It is a very complex issue at this point and I am not sure that I have the specific answer to provide to you.

Chairman **Glenn**. Dr. Fields, how do you handle that in DARPA? Do you fund research done by offshore companies? How do you handle this issue?

Dr. **Fields**. Well, we do extremely little. I cannot remember even one case at the moment, but there may be one or two. But by and large, the issue for all of these is to try to maintain a competitive advantage, and we have to look at the tradeoffs. Sometimes there is an American owned firm that wants to do work abroad, and in other cases there is a foreign-owned firm that wants to do work in the United States. And frankly, I prefer the latter, because that provides jobs for U.S. scientists and engineers and U.S. workers.

Of course, what you would like is everything, and those get the highest priority. So I have to agree with Juan, that there is not any simpleminded rule. We look at every single proposal and try to see which are the best ones.

Chairman **Glenn**. It is not a small item. I was concerned enough about it a few years ago on SDI. I was a supporter of SDI research, but so much of that money was being programed for others and being used abroad. They made no bones about it, the foreign governments that wanted to get in on SDI research. And, they did so with a statement that they wanted to build up their own scientific infrastructure, their own labs, their own qualified people, as well as do the research.

And so we put some rather strict limitations in the SDI program, which I am still being criticized for over in the Defense Department, but so be it. I think it was a good move because we are dropping back in the amount of research that we do in this country. I think we are a strong Nation because we have led the world in education and in basic breakthrough research, those two very fundamental things.

We now begin to see our lead in research and in education, I might add, being diminished drastically, and I want to see research dollars spent in this country as much as we possibly can. So I think if we go ahead and vote for more money for HDTV, we would probably want to put on some location restrictions too.

Dr. **Fields**. If I might comment, Senator, the problem is even more complicated than you say, although what you say is completely right. Because we find lately that U.S. firms, at the conclusion of a contract with the R&D done in the United States, subsequently license the results for production to foreign firms. And that is something that is very difficult.

We have tried to take a position in DARPA that we are to retain rights to the Government but then give an exclusive license to the performer, but without sub-licensing allowed, in order to try to control that.

Chairman **Glenn**. We have limited research dollars. I have been the biggest advocate in Government of trying to expand these research dollars. You and I have had conversations about that in the past and the importance of it, and I will continue on that quest, I can guarantee you. But no matter how many research dollars we spend, there is always going to be competition for every one of those dollars. There are competing technologies that merit a lot of Federal funding. We have semiconductors through Sematech, supercomputers, superconductivity, a supercollider, a whole bunch of things that we are interested in.

Where does HDTV rank among these various technologies?

Dr. FIELDS. Well, as you can see, I consider HDTV within the context of the electronics industry as a whole and I do not see anything that I put at a higher level in my priorities than maintaining a strong electronics base in this country.

Chairman GLENN. You would put it number 1, then?

Dr. FIELDS. Well, I would put electronics number 1. It is the largest industry in the country and it is probably the dominant technology of this century.

Chairman GLENN. Mr. Benitez, how do you look at it?

Mr. BENITEZ. Mr. Chairman, if I could complement what Craig just mentioned, I think the best way to evaluate that question is, to once more look at what the Japanese are doing in terms of the substantial commitment and investment that they are making to HDTV. And again, the Japanese, based on historical records, have done very well in predicting what emerging technologies may do for commercialization purposes.

So based on that scenario, I would say that HDTV should be a very top priority in terms of technological and, potentially, economic development for this country.

Chairman GLENN. The basic concept for HDTV, where was that developed? Was that developed here or Japan or where? Do you know, either one of you?

Dr. FIELDS. I know the earliest development was in Japan, at least the earliest development I know about. I do not know who was number 1 first in that. Perhaps some of the other witnesses will go back 20 years.

Mr. BENITEZ. I do not have a specific answer, Mr. Chairman. Obviously, based on the documentary reports, the Japanese have definitely taken the initiative and the lead on it.

Chairman GLENN. So you do not know whether this was something that they developed on their own or whether this was another one of a long list of things that we basically had the idea for or did the very fundamental research on and then they took it and ran with it.

Okay, thank you both very, very much. It has been very interesting.

Our next panel, is Mr. Tom Long, Vice President and General Manager, Technology Group of Tektronix Inc., representing the American Electronics Association, accompanied by Ms. Pat Hill Hubbard, Vice President, Education and Science Policy, American Electronics Association; Mr. Peter McCloskey, President, Electronic Industries Association; Dr. James Tietjen, President and Chief Operating Officer, David Sarnoff Research Center; and Mr. Richard Solomon, Media Laboratory and Advanced Television Research Program, Massachusetts Institute of Technology, who undoubtedly is going to talk to us about the costs of HDTV.

Mr. Long, if you would lead off for us, we would appreciate it.

TESTIMONY OF TOM LONG, VICE PRESIDENT AND GENERAL MANAGER, TECHNOLOGY GROUP, TEKTRONIX, INC., REPRESENTING THE AMERICAN ELECTRONICS ASSOCIATION,[1] ACCOMPANIED BY MS. PAT HILL HUBBARD, VICE PRESIDENT, EDUCATION AND SCIENCE POLICY, AMERICAN ELECTRONICS ASSOCIATION

Mr. LONG. Thank you, Mr. Chairman and members of the Committee. I am Tom Long, Vice President and General Manager of the Technology Group at Tektronix in Beaverton, Oregon. I appear here before you today on behalf of the American Electronics Association to discuss the Congressional Budget Office report entitled "The Scope of the High Definition Television Market and Its Implication for Competitiveness."

The American Electronics Association, or AEA, as it is better known, is a 46 year old national nonprofit trade organization of some 3,500 companies and 45 U.S. engineering universities. Our members design, manufacture or conduct research in electronics, electronic components and related information technology products.

Now, getting back to my own organization, Tektronix is a $1.4 billion corporation established in 1946. We are a leading manufacturer of electronic products and systems in the areas of test and measurement, computer graphics, and communications. In fact, Tektronix supplies virtually all the test and measurement equipment used for HDTV today. Tektronix is one of 36 AEA member companies that funded the development of a business plan to establish a U.S. based HDTV industry, and I am a member of the AEA Advanced Television Task Force.

My written testimony contains several points of rebuttal to the CBO report. I am going to deviate from that testimony to put the HDTV comments in an economic context so that you can perhaps better understand the gravity of the situation. I will leave it to Pat Hubbard to deal with certain points in the CBO report.

I would first like to begin by discussing the fact that the Japanese have an industrial policy, and it is one of export. This is well documented at the Harvard Business School, so I will not go into the details They also have a program that is being executed with utmost precision, and that is they identify a critical technology, they close their markets, and they build an infrastructure; that is, they develop an engineering, manufacturing and marketing capacity. They control the market by dumping in the U.S. market, and maintaining high prices in their home market.

Once they accomplish that for a given technology, they move on to the next one. You might rightly ask how can they do this? They have generated tremendous amounts of capital for industrial purposes. In Japan the interest rate peaks at about 4 percent for industry loans. Loans are not available for an individual to buy a house and consumer loans come at a very high interest rate. Many loans are provided to industry at 0 to 2 percent.

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[1] See p. 102 for Mr. Long's prepared statement.

Very recently a consortium of Japanese companies received a grant for $75 million to develop what they call a "greater than one meter square flat-panel display." Another Japanese company has received $1 billion at 0 percent interest. Fujitsu received $400 million at 1.5 percent interest to insert fiber optic technology in computers.

Now, let's take a look at the United States. We all know that we spend about 7 percent of GNP on defense and the Japanese spend 1 percent. We also have an infrastructure of EPA, OSHA, Social Security and Medicare to support. Now, I am not against any of these things. I think that probably each one of them could be run more efficiently than it is, but that is true of industry as well.

What I am trying to point out is that the United States is a high-cost place to manufacture. I can put a rational argument together that suggests that the United States has a 25 to 30 percent cost disadvantage compared to the Japanese. I have seen reports in Japan that when the yen was decreasing, or appreciating against the dollar, that most Japanese companies could remain competitive even at 90 yen to the dollar, which means that they have a lot of headroom or margins in their products.

More recently, we have read that the cost of manufacturing in Japan has exceeded that in the U.S. Recent MAPI studies will show that the average labor cost per hour is still higher in the United States than it is in Japan. The real difference shows up in the professional ranks. The Japanese can put an engineer to work just out of college for about a third to a half of what I can, and this is on a fully loaded basis. To put it another way, they can put two to three times as many engineers on a project as I can for the same money. In simple terms, the United States, again, is an expensive place to manufacture.

Now, some may call low cost loans or development money the beginning of an industrial policy. But I ask, what is the alternative? Now, let me focus on the DRAMs that were previously discussed by other witnesses. In the 1981-82 time frame, the Japanese began selling DRAMs in the U.S. market below their variable cost. The net result was that except for Texas Instruments, all the U.S. manufacturers quit the DRAM business, but before they did they had incurred $2.5 billion in losses on those product lines.

Today the Japanese control 85 percent of the world's markets in DRAMs. Now, if you believe in the Boston Consulting Group's learning curve theory, it will be impossible to catch the Japanese without extraordinary efforts on our part. I think that HDTV presents one of those rare opportunities. We have heard a previous witness suggest that an HDTV receiver will contain as much as 50 megabytes of memory. If that is true—and I think it is—and some of the projections hold true as to the volume, then the HDTV business will exceed that of computers in the consumption of memories.

The Japanese are not putting $3 billion into the DRAM business or DRAM manufacturing resources just on speculation that the electronics market is growing. They are doing this very specifically for the HDTV market that they are projecting will come on-stream.

Now, another point I would like to make is that the Congressional Budget Office should compare the tax contribution of those products made in the United States, including components, versus those bought from the outside. I estimate that if the United States does not get into the HDTV game and control it, we can expect balance of payment problems somewhere in the order of $200 billion to $500 billion over about a 10 to 15 year period.

I would also like to address the issue of a civilian versus a defense agency maintaining or administering HDTV-related programs. I think that we are very fortunate to have a person like Dr. Fields in charge of DARPA. He has certainly seen the handwriting on the wall very early, much earlier than many people did I think it will take at least 5 years to develop an infrastructure similar to what DARPA has for administering its advanced imaging program and I do not think we have time to do it. Thank you.

Chairman GLENN. Thank you very much.

Ms. Hubbard, do you have a separate statement?

Ms. HUBBARD. I would like to make some brief comments, Mr. Chairman.

I am Pat Hill Hubbard, Vice President of AEA. I have had responsibility for exploring U.S. reentry into consumer electronics via HDTV for a little over a year. It has been quite an experience.

I would like to just focus, if I may, on some specific comments relating to the CBO report. As the person in charge of developing the AEA report, I want to call attention to the CBO report's basic premise, which I think is erroneous. CBO took AEA's report as an econometric study and yet twice in our small report we state that it is a working document.

I would like to read you an excerpt of AEA's report:

> Since it is impossible to know when HDTV's ripple effect will occur, that is, when the new product spinoffs may erode market share in the non-consumer electronics field, quantifying market impact requires extensive time and resources beyond those of the AEA HDTV task force. This working document, therefore, will be modified as other studies bring information to bear on it.

And in point of fact, many times thereafter AEA's board of directors has called on the Government, specifically through the National Academy of Engineering and the National Research Council, to conduct third party studies that would give us some econometric data to work with.

So the assumption that AEA's projections should be treated as concrete numbers is really erroneous. CBO's chart (Figure 2, page 9), which is very striking, is quite misleading.[1] It uses AEA numbers and states that they are on the high end. Frankly, it is a point of pride that we took a very conservative approach to market penetration focused slowly on television market penetration. This is what the chart does, but it ignores all other fields. AEA selected to look at HDTV as an evolutionary technology. We believe it is. AEA's report contians figures for IDTV and EDTV and HDTV in those market projections. CBO, however, ignored the evolutionary aspect of HDTV and focused just on the third, the end, the pure angle of HDTV chip consumption and, again, ignored the evolutionary nature of HDTV.

CBO also erroneously states that AEA assumes HDTV will be a success from the outset. Again, on the contrary, AEA's conservative projections are based on the assumption that refinements will occur and market penetration will be slow.

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[1] See p. 75.

I have to say again that no one else in the United States has undertaken a ripple effect study, and no one seems to be willing to do it—at least when I asked in this town—for less than 6 months and $100,000.

I also would point out that anybody can dispute forecasts because only time will tell whether they are accurate or not. But I think it is especially faulty to focus on a point in time and to dispute those figures without another study to compare. We welcome it; we want it; we urge it. Perhaps this Committee could encourage that third party study.

But I think that to ignore the universe of knowledge that has been generated since AEA's November 1988 report is unconscionable. The 35 plus reports submitted to Representative Markey in February is just one of many sources of information that CBO ignored. Certainly Craig Fields gave you an example of the many reports that are out there.

I would like to just end my comments with a quote from a book that I believe Dr. Fields mentioned, "A Japan That Can Say Know," which was published in January. It is a chilling quote from Shintaro Ishihari, who co-authored the book with Akio Morito. Shintaro Ishihari, who is a member of Japan's Liberal Democratic Party says:

> If one does not use Japanese semiconductors, one cannot guarantee precision in targeting missiles. No matter how much the Americans expand their military, they have come so far that they could do nothing if Japan were one day to say we will no longer sell you chips. For example, if Japan were to say that it will sell chips to the Soviet Union and not to America, that would instantly change the balance of military power.

There is a crossover connection between economics and military security that has not been addressed by CBO's report. Today's computer age is the backbone for tomorrow's information age. I am asked again and again, why is electronics so different than steel and autos? I would say that Ishihari's statement basically points out the difference.

Electronics is the infrastructure. It is going to underpin and shape the world's economy, and potentially its political organizations, in the 21st century. It is not just an industrial segment. And it is our belief, after much study, that high definition technologies—not just television—will be at the hub of the information age's infrastructure.

Every $1 billion in trade deficit accounts for 12,000 lost U.S. jobs. Lost market share translates into trade deficits. The United States needs to gain an industry to retain an industry. I must say that the CBO study does not help in this up-hill effort that U.S. industry is trying to make, in cooperation with Government, and it definitely helps keep us at the bottom. Thank you.

Chairman Glenn. Thank you, Ms. Hubbard.

Next Mr. Peter McCloskey, President, EIA, Electronic Industries Association. Mr. McCloskey.

TESTIMONY OF PETER McCLOSKEY, PRESIDENT, ELECTRONIC INDUSTRIES ASSOCIATION

Mr. McCloskey. Thank you, Mr. Chairman, and good morning. I would like to have my entire statement printed in the record.[1]

Chairman Glenn. Without objection it will all be included in the record. In fact, all of your longer statements will be included in the record. I know you are all summarizing to some extent here. Your longer statements will be included.

Mr. McCloskey. First of all let me tell you a little about EIA. We are 65 years old. We started out as the Radio Manufacturers Association and we have a tremendous background and history in writing standards in the electronics industry and representing the electronics industry.

This year the electronics industry had a record breaking performance, it was $248 billion in sales and our exports were up 38 percent. There was an 18.6 percent rise in imports so that this year we actually improved our performance relative to imports with exports. And there was a 27 percent drop in the electronics trade deficit.

I think I will try to focus on some of the issues that were presented, because I think there are misconceptions and a lot of perhaps very good ideas that are merged one with the other. First, I think the CBO report is a valuable contribution. I think it takes some of the emotion out of the situation. I think it is certainly clear that the CBO report focused on consumer electronics and the HDTV set, which is viewed as a consumer electronics product.

If you redefine HDTV to be all of these applications, whether it be the display in an airplane, or everything else, then you are really in a different business. The consumer electronics business is a business all of its own. It is an important business. In this year—1988—it was roughly $30 billion in factory sales including the manufacturing value of imports into the United States.

I think it is important to put that $30 billion in perspective with the $248 billion that the U.S. electronics industry represents. The reason that most companies got out of the consumer electronics business in the United States was it was a low profit business. They were not getting a good return on investment and they moved up the ladder. Whether that is shortsighted or not, it really is the fact.

One of the shortcomings that was mentioned by the representative from the Commerce Department, Mr. Benitez, in the CBO report relates to the issue of whether or not companies would buy semiconductors outside the United States or they would buy them from U.S. sources. The fact of the matter is that when the consumer electronics companies were U.S. owned, they diverted to foreign supply for electronic components. The reason they did that was because they could get them cheaper and they were more reliable at that time. Commodity products were not something that the U.S. component industry was interested in providing. They were, again, moving up the ladder. So they abandoned them.

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[1] See p. 146.

When RCA was in the business and had its own subsidiary, it still went offshore with some of those components. So it was not just that issue. You are going to try, in a global economy, to get the best buy that you can get. And I do not think there are very many U.S. companies that can operate any other way than to try to get the best components they can get. So if they have a captive subsidiary that provides components, the general manager of that subsidiary is in competition with not only other U.S. suppliers but the rest of the world and he has got to be able to meet that competition, and when he does, he gets the business.

The nature of the television business is such that when the yen got stronger and the dollar weaker, the margins became extraordinarily thin. In my judgment, there has not been a company in the consumer electronics TV business that has made money over the last 5 years. So as we go into the HDTV business, while it initially will be a higher margin business—it is going to be extraordinarily competitive.

I think one of the other things that we should look at is the fact that U.S. television production has come back to the United States. Virtually all of the 20 inch and above sets last year were made in the United States, with a very significant U.S. manufacturing content, around 70 percent. The estimate of the Nathan study is that the same will be true of HDTV, particularly if it is tube technology. We are looking at most, if not all of the HDTV sets being manufactured in the United States by American workers. We are talking about the tubes being made here, we are talking about the chassis being made here, and hopefully we are talking about some of the electronics being made here.

It is true that right now the U.S. semiconductor industry is leading the world in digital signal processing. They have every opportunity to get that business and hopefully they will. AT&T has announced an arrangement with Zenith and hopefully they will get the business from Zenith.

I think one of the other misconceptions is the market and who has the market. We hear about the Japanese, and it is true, the Japanese have a significant market share. But the Japanese are very competitive amongst themselves. The largest market share in the United States, roughly 23 percent, is the old RCA business, now merged with GE, now owned by Thompson. They have 23 percent. The next largest is Zenith with roughly 11 percent. The next is Phillips, which is the old Sylvania-Philco line, with 10. The largest Japanese company market share in the United States is Sony and they have under 7 percent.

So it is not just one company, it is many companies. They are all competing very vigorously and they are, in fact, manufacturing in the United States. I think that if we were to focus on anything, we probably ought to focus not on television but on VCRs, which are still primarily made in Japan. However, I do agree and do support the concept of DARPA funding for display technology, for digital signal processing and the like.

But this is not a simple business. The estimate was made of 50 megabytes of memory. I think that is on the high end. On the low end is zero memory in the Phillips system. They are not going to use memory, it is going to be in real-time and they do not need it.

So it depends on the implementation, it depends on the standard that is adopted, it depends on a number of factors.

I think, in summary, the U.S. electronics industry is very vigorous. If you take a look at the period 1984 to 1987, the United States lost considerable market share in the world. But if you take a look at the U.S. electronics industry and its U.S. manufacturing and you look at Japan in the same period and its manufacturing, the United States actually grew at a slightly faster compounded annual growth rate relative to their respective currencies. The major factor that hit the United States, there is no question about it, is the value of the dollar and what happened to it. And we became noncompetitive as a result of it, and it is a long road back to becoming competitive again.

The macroeconomic factors are extraordinarily important. We suggest the investment tax credit for research and development, resolution of the 861 issue, the reduction in capital gains tax, joint manufacturing, if necessary. These are things that we can do, but I think the most important thing we can do is to bring our budget back in to some sort of alignment and improve our balance of payments. That will help the U.S. industry become competitive again.

Another fact I think that is interesting, the National Science Foundation reported, on your point about research and development dollars being scarce, that for nondefense R&D, the United States funds about 35 percent of the research done in industrial laboratories. In Japan, it is 2 percent. So there are, obviously, things that we can do to get a better bang for our buck out of our R&D dollars. And I would support in concept your idea of a civilian agency focused an improving the efficiency of our R&D in the United States.

I think that covers my points, Mr. Chairman. Thank you.

Chairman GLENN. Thank you, Mr. McCloskey. I was at a conference this past weekend in which one of Mr. Solomon's cohorts from MIT was a speaker. He indicated that our spending on R&D as a percent of GNP is about 1.7 or 1.9.

Mr. MCCLOSKEY. I think 1.8.

Chairman GLENN. And that Germany's is 2.5.

Mr. MCCLOSKEY. For industrial R&D.

Chairman GLENN. Germany is 2.5 and Japan is 2.9, I believe, if I remember the figures correctly. They may be out of the book that you have there, Mr. Solomon, I am not sure.

Mr. MCCLOSKEY. I think in the aggregate, including defense R&D, we are up about 2.6.

Chairman GLENN. This was strictly civilian.

Mr. MCCLOSKEY. In civilian we are down about, I think it was 1.8. But on an absolute basis, Senator, the one 1.8 represents more than Germany, France, and Japan combined.

Chairman GLENN. Dr. Tietjen, our next witness, is President and Chief Operating Officer, David Sarnoff Research Center.

TESTIMONY OF DR. JAMES J. TIETJEN, PRESIDENT AND CHIEF OPERATING OFFICER, DAVID SARNOFF RESEARCH CENTER [1]

Dr. TIETJEN. Mr. Chairman and members of the Committee, I appreciate the opportunity to appear before you this morning to discuss high definition television technology and its possible impact in the United States. I think this Committee is to be commended for its interest and initiative on this issue. It is important that we develop a national strategy for HDTV development in this country. But this is a very complex subject with many ramifications and I think it is important that we all try to understand it as well as we possibly can.

The David Sarnoff Research Center in Princeton, New Jersey, is a subsidiary of SRI International of Menlo Park, California, which is an American company. We were formerly RCA Laboratories, and as such we are the inventors of the NTSC color television system currently used in the United States, Japan, and in other countries comprising about one-half of the world's television viewers.

In addition to the NTSC system, the Sarnoff Center has also developed many of the critical components and technologies responsible for today's television and semiconductor industries, including camera technology, color television picture tubes, addressable liquid crystal displays, and the CMOS technology used by the semiconductor industry around the world, to name just a few.

In addition to Sarnoff's direct involvement in technology development, I have had substantial experience in transferring technology into the marketplace and I am quite familiar with the business environment of the various industries related to high definition television.

At present, Sarnoff is working to develop an advanced television transmission system specifically designed to meet the unique needs of the American viewing public and television industry. Our system is called Advanced Compatible Television. It is a two step evolutionary approach for moving America into the advanced television era quickly and in a manner which will not leave us disadvantaged relative to foreign economies.

What you asked me to comment on today was what will be the impact of HDTV technology on a variety of related industries. To answer this question, I would like to focus on 4 areas. First, I think we can draw upon the history of color television and the dual use technologies which have been derived from it.

Second, there is a growing convergence of technologies derived from different industries indicating that each will rigorously impact and enhance the others. And third, for the United States to have any impact we must set an HDTV standard as rapidly as is practical. And last, to ensure our industrial competitiveness in this and related areas, I believe Government support and action are imperative.

Let us consider the validity of the dual use technology concept of high definition television which has received so much attention lately. For example, how important is high definition television technology to the computer industry and vice versa? Looking back into the past, there are paradigms which illustrate a close sharing of technologies.

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[1] See p. 242 for Dr. Tietjen's prepared statement.

It is clear that conventional television was built around the invention of the cathode ray tube display and vacuum-tube based image pick-up tubes or cameras. But it is interesting to note that the computer industry, particularly the personal computer industry, inherited the cathode ray tube technology from television.

In the late 1970s, during the birth of the personal computer industry, the display technology that was required existed. It was low cost, it was already high volume. By incorporating this technology borrowed from television, the computer industry was, in a sense, liberated from a costly and time-consuming development, thereby enabling the industry to concentrate on developing the market and growing rapidly. Today consumer electronics contribute to industrial and defense electronics. For example, much of the frontier research in photo-electronics is being carried out by consumer electronics companies manufacturing laser discs.

Photo-electronics are of growing importance in communications and computers and may soon be critical path technologies for the most advanced space communication systems and supercomputers. The market size and production base of consumer electronics provides the financial capacity and the manufacturing know-how to develop photo-electronics.

The U.S. defense industries and space industries are greatly assisted in the funding of the prerequisite research needed to support the development and manufacturing capabilities ultimately required for their pursuits.

Beyond these examples, there is the simple fact that we are witnessing a rapid convergence of technologies. As development and innovation draw technologies closer together, the impact of one upon another will be more vigorous. Advanced television is a beneficiary of the digital integrated circuit and semiconductor memory technology developed for the computer industry. High definition television would not exist without the technological developments that have been primarily funded by the computer industry.

Conversely, computers will use more and more video displayed on high resolution screens and high definition television receivers will have a high semiconductor and memory content, and the telecommunications industry will benefit from both of these.

There is still a long way to go in these technology developments and industry interaction is likely to expand. For example, a true consumer high definition television display is not available yet anywhere that I know of around the world and it may be sometime before this component is developed. As it emerges, it likely will impact more than just the consumer electronics industry.

High definition television will "de-mature" the television industry, giving rise to new services, new programs, new transmission systems and new receiver sets. High definition television will over time replace the current television industry with an entirely new one. These new elements will stimulate economic growth as the industry responds to new opportunities in substituting for old businesses and in identifying entirely new ones.

There are many estimates of the size of the new television industry and the impact on the television industry suppliers, and they all indicate that this is a significant industrial growth opportunity. While the attention surrounding high definition television is focused on its inherent consumer orientation, as DARPA has recognized, it has a variety of other potential applications. The high definition television cluster of technologies constitutes a strategic set which will affect many industries, including defense.

In a rather brief, cursory attempt to identify those which would be affected, we came up with many different industries, as you heard from Craig Fields. These include electronics, communications, computers, medical technologies, publishing, avionics, Postal Services, et cetera.

The continued development of this technology base is of utmost importance to the vitality of the United States Research, development, and production within the United States is essential to ensure the soundness of our technology base and its accessibility at reasonable price to other industries.

While it seems rather clear that high definition television will, in fact, have a substantial impact on a variety of industries, the degree of impact and the timing is very uncertain. The specific high definition television transmission standard is likely to play a significant role in establishing the dynamics of the U.S. transition into the high definition television era.

Without knowledge of the specific standards to be chosen, it is extremely difficult to predict high definition television timing and growth rates. For the reasons I have discussed, I feel it is very important for the Government to help ensure that the United States establishes a strong position in high definition television technology and expertise. We simply cannot afford to ignore the potential impact and ripple effects of this technology, even though it may be sometime in the future.

One very important issue is the establishment of an HDTV standard which will result in the most robust and the fastest growing high definition television industry. What is needed is a single standard for all television delivery media which can be implemented rapidly so that the United States high definition television industry can develop quickly and not fall behind the power curve versus Japan and Europe.

The FCC's Advisory Committee on Advanced Television Service under the leadership of Richard Wiley is making excellent progress towards selecting a transmission standard, but we need to move very quickly. If we wait too long, we may finds ourselves behind and unable to catch up in a critical technology race with broad implications for a variety of strategic industries. Thank you.

Chairman GLENN. Thank you very much. Mr. Solomon, of the Media Laboratory and Advanced Television Research Program, Massachusetts Institute of Technology. Mr. Solomon.

TESTIMONY OF RICHARD JAY SOLOMON, MEDIA LABORATORY AND ADVANCED TELEVISION RESEARCH PROGRAM, MASSACHUSETTS INSTITUTE OF TECHNOLOGY [1]

Mr. SOLOMON. I am afraid you are asking for a number before I get to my paper, but I will hold it in suspense to the end. [Laughter.]

Chairman GLENN. That will keep the crowd today.

Mr. SOLOMON. It will give my colleagues a few more minutes to generate some figures here.

I appreciate this opportunity to comment on the important issues being discussed here. My name is Richard Jay Solomon, I am a consultant in telecommunications policy and I speak as a private citizen.

Since 1978 I have been a Research Associate in Communications Technology and Policy at MIT where I am currently working on several projects related to high resolution systems. I am also an adjunct professor at NYU.

Over the last 10 years, industry/government consortia in Japan and Europe have invested over a billion dollars in R&D in the area of high resolution systems. Thus far, the lone American purely private consortium has invested a little over $5 million. That is less than 1 percent of what our European and Japanese competitors have invested. In recognition of this situation, we have heard a number of proposals to counteract the European and Japanese initiatives by leaders in American industry and Government.

To some readers of the CBO report, it is just these proposals that the report appears to discredit, unfortunately. The CBO report seems to have accepted the mistaken, but oft repeated view, that high resolution systems are important only to television sets. Now, I will not belabor that point.

I am not going to read all of my written testimony, because I would say what virtually all the witnesses this morning have agreed on: that high definition TV is not just about television. We can find more and more examples. And I think I even heard the representative of CBO admit that, too, but maybe I was wrong. But to anyone who thinks that HDTV is only about television, and that television sets are not very important, they are committing a double error.

Mr. Tietjen just pointed out how important television is to the personal computer industry. This lets me skip right to some important points, because we have all said that.

In the three studies that the CBO looked at, they looked basically at growth. Most bullish was EIA, most conservative was AEA, which projected essentially the same market but with a 10 year lag. I have no problem with those market estimates. Even television will be a very large market, no matter how you look at it.

More importantly, the CBO report cited a very important study performed by MIT at its Audience Research Facility 2 years ago. I did not do that study, though I was there when it was being done, physically. I do have in the room here a colleague of mine, Dr. Lee McKnight, who basically ran the study, along with Russell

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[1] See p. 247 for Mr. Solomon's prepared statement.

Newman, who is not here right now, and he can answer any detailed questions about it.

In general, neither the CBO report nor those who have attempted to use the MIT study to demonstrate that there is no real demand for HDTV understand really what was found. They have simply missed the point. The MIT study tested the prototype Japanese NHK high resolution system and found that this system had not yet advanced to the point where consumers were interested. That is all it did. Little has changed since our study was done.

What still is needed to stimulate the HDTV markets are larger and brighter high resolution displays. And such displays for the consumer market, for the home market, must only have a modest cost differential beyond that of existing TV sets. As Dr. Tietjen says, we have not arrived at that yet. The Japanese have not shown us anything that meets those requirements. They have shown some interesting pictures, but not what we could say is a consumer industry. It is not here yet.

There is an opportunity here. This raises the important question: what is the nature of consumer demand for HDTV? I want to be very clear about this because there has been considerable misinterpretation of the MIT results, right from the first time we gave the report at the National Association of Broadcasters in 1988.

The study does not conclude there is no demand for HDTV. On the contrary, it concludes that there is a limited demand for expensive, relatively small cathode ray tube displays judged under normal home viewing conditions. That is what we studied at the Audience Research Facility. We have the facility set up sort of like a livingroom so it feels like you are at home.

The research that we did, the new work currently underway, concludes that whomever wants to enter the high resolution marketplace has a special opportunity, not a limited marketplace. The studies found that the Japanese technology was not optimally designed, and we are just talking about displays. If we want to divert later, we can talk about the entire NHK system as proposed, because it is very, very deficient, but that is just an aside.

The United States does have an opportunity to leapfrog the foreign competition by introducing larger and less expensive displays and much higher levels of resolution. DARPA's recent initiative focusing on advanced digital display technology was well conceived in view of the conclusions of the MIT study. It is understandable that the demand study cited in the CBO report concentrated only on home entertainment.

At the time those studies were made, the principal public discussion of high resolution was for its utility for future entertainment TV Despite others, including ourselves, talking about the other applications, it only penetrated very recently that there really were other applications that were important.

So HDTV was conceived only in terms of a straightforward extrapolation of today's television. But with more lines on the screen and maybe better sound.

In that, the NHK work is commendable. They have done a lot of work in Japan, but what they did is to take 70 year old television technology and just extend it straightforward. There are many who doubt that future television is going to be the same as the past.

The impact of the MIT study probably shook the proponents of simple HDTV. It took a while for this to sink in, and now we have the term, "High resolution systems." It wasn't even coined then. The first time I heard it was at the IEEE workshop, which I will discuss in a moment, in February of this year.

Now, most of us recognize that high resolution systems include a broad range of multiple use, very high definition displays. I will not go over the list of all those. We have heard them from quite a few people today. Dr. Fields gave a very good description of that, but there is one major illustrative example which is useful:

If we are trying to estimate the potential size of the non-entertainment market, which I hope would be a follow-on to the current CBO work, we could start with the FAA contract which was recently awarded to a foreign supplier, Sony, for high resolution displays to modernize the U.S. air traffic control system in the next few years. This contract will be for up to 10,000 2,000-line monitors. We have a couple of these at MIT, they are quite impressive. They are very big and they are very heavy. They cost roughly $40,000 apiece, at least that is what they charged us for them. We do not get these things free.

Just extrapolating that alone, we get close to half a billion dollars for the contract, but there are other related costs in electronics, memory buffers and drivers. The FAA will not release that information, at least not to us. We have requested it. There was testimony to Congress this year at other hearings that the ceiling may exceed a billion dollars over the lifetime of the contract. This is one small niche market, and already it is over a billion dollars, and it is all going to a foreign supplier. Even a nominal 10 percent profit margin on this single award is comparable to the funds currently being discussed for U.S. high definition R&D by Congress. And there are other markets.

The next issue beyond the market is the linkages that we hear a lot about. The fundamental question of linkages, from my point of view, is whether the value of a market such as HDTV receivers is simply proportional to its projected sales, as contended by the CBO report, or whether the value is greater, just as the value of any link in a chain can approach the value of the entire chain.

From that point of view, I would say the high resolution technology is a vital element for the U.S. manufacturing base in electronics and associated technology. The IEEE workshop, and I would like to append a copy of the final report to my testimony, was February 13th at the National Research Council. It illustrated the electronics "food chain" with a very interesting chart. Loss of this link, given current trends, could cost the Nation the entire chain—its entire electronics base.

This is cited several times in the report.

Now, how would the linkages manifest themselves for that to happen? Well, there are several ways. As suggested by the FAA example, a company which has developed a non-entertainment application will be better positioned both technologically and economically to succeed in entertainment markets. The next stage for the non-entertainment market would be lost-cost manufacture of reliable high resolution displays. We have seen that with fax. Low cost fax followed high-end xerographic machines. That market is almost totally dominated by overseas manufacturers—the low cost fax. We now have them in our homes. They have become cheaper than high-end TV sets; in fact, cheaper than PCs.

Conversely, firms which have mastered high resolution system technology for the consumer market will be better positioned for the next stage. We saw that, and it is documented in the book that everyone is staring at here, "Made in America," how the Japanese took their success with consumer VCRs and technology—which was wholly American to start with—and permitted them to dominate production video systems.

We are getting very close to the question you were asking: what are we going to do about broadcast television, because it is related to these issues.

There is another very important fact that is extremely important on down the line, and that is that computer and television technology are merging. There are some of us who cannot see how a TV set of any kind, particularly on the high end in the next few years, will not really be a computer. To think that you can do high definition television without any memory in a set is fantasy. Without memory would require having a very broad band transmission channel.

One of the key problems with the Japanese system—diverting from my remarks right now—and one of the major problems that we are facing in HDTV, which the FCC Advisory Committee is doing a very good job of addressing, is how do we pump that kind of information on narrow, yet expensive band width, and that would include fiber optics too—fiber may be cheap, but the switches are not and the nodes are not—and produce a reasonably successful picture on the consumer end.

One way to do that, and probably the only way to do that, is to use a lot of computation and memory in the sets. I am reminded that they have numbers that they want to get out here. I will not belabor the PC point any further. But whittling away at segments of industry is not a new story.

In last week's New York Times there was a quote from a Japanese executive of an electronics firm:

> Piece by piece, you [the U.S.] stopped working on the small technologies that added up into the big ones. Now a billion-dollar market is in sight and people are beginning to figure out that you pay a price for those little technologies.

The reference was to digital audio tape machines, another technology we seem to have lost all control over.

More ominous consequences of linkages could arise in different ways. For example, suppose large foreign, vertically-integrated producers of high resolution displays compete with U.S. assemblers of high resolution television sets. Suppose that further the U.S. firms have no choice but to purchase displays—the picture tube, if you will—or the flat screen, from the foreign, vertically-integrated competitors since the foreign firms are the sole suppliers.

This could happen if we do no work in the United States. Since displays today constitute roughly half of the end-product content of a TV set, a small price increase in the display by the integrated foreign manufacturer could eliminate the profitability for the U.S. manufacturer. That is not inconceivable. Just think of the price increase we have had of DRAMs in the last year by a factor of four when falling prices were expected instead due to the learning curve.

Recently Japanese firms were charging roughly three times as much for DRAMs outside of Japan as they were at home. The mere existence of such capability could motivate U.S. manufacturers to leave, or not to enter, an end-product market.

And without getting into a very complicated discussion, I just want to mention one thing. There are more frightening consequences of linkage that could happen if the content of the television—or the computer software—were controlled by the same foreign source as controlled the pace of introduction for high resolution equipment. The question is extremely complex. We have only begun to look at some of these things. Now what is the role of Government? What is the proper role of Government in monitoring and promoting the health and independence of U.S. industries in general, and high resolution systems in particular? The two recent IEEE workshops I have referred to reached broad consensus that private/public cooperation can be enormously fruitful. Government can be extremely helpful not only in establishment of U.S. high resolution systems capability, but also to the health of the entire U.S. electronics industry.

We have extensive historical precedent for this. We could begin with the growth of railroad infrastructure 150 years ago, which opened up the continent in the 19th century. There are related examples. Very closely related to HDTV was the formation of RCA, itself, by the U.S. Navy after World War I. I have a memo I wrote about that which I have attached to my testimony. The formation of RCA contributed significantly to U.S. leadership in consumer and military electronics for decades. It certainly helped a lot before and during World War II.

The development of radar and affiliated military electronics, coordinated by MIT during World War II—another example of strong industry/government cooperation—put the U.S. far ahead of other countries for decades. Formation of COMSAT by Congress established the U.S. as the world leader in satellite communications; and in view of the 20th anniversary of the moon landing, we have to mention the Apollo program. There are others.

An absence of effective cooperation in recent decades between the private and public sectors for commercial and industrial research, development and manufacturing, has contributed to our loss of an international competitiveness in certain key industrial areas. It is the subject of this book by the MIT Commission on Industrial Productivity, entitled "Made in America." I have brought enough copies for all the Senators who are members of this Committee, plus some of their staff. I will hand them out.

I recommend reading the book. It is frightening. It is almost a horror story when you realize the situation we got ourselves into. There was an excerpt published last month in Scientific American which I will append to my testimony.

I am delighted this Committee is now focusing so much attention on this critical problem. Thank you.

Chairman GLENN. Thank you very much, all of you.

Mr. SOLOMON. Oh, the answer.

Chairman GLENN. The answer, yes. I want to get the answer here.

Mr. SOLOMON. I was not quite prepared for that. We have thought about it. I have two of my colleagues here who were scribbling numbers on the back of a pad. I could give it to you the quick way, which is one number, and I could give you a quick idea of how we have reached to it.

There are roughly 1,300 television stations in the United States, some are small, some are big. The current cost for a camera, a VTR and display in Japan for HDTV is roughly half a million dollars. If you assume a straightforward replacement of existing cameras, VTR, studio equipment, mobile equipment, a studio usually using three cameras, you have at least one VTR, but these things break—you have to have some backup.

We have gotten a number between $2 billion to $10 billion for direct replacement in the U.S. broadcasting industry. I am probably sticking my neck out. I am sure the trade press is going to shoot me down because we left something out, but we like to feel that with an order of magnitude estimate, from an engineering point of view, it gives you a general idea. That does not mean that it is going to cost $3 to $10 billion right away.

However, we are not going to have—and on this I will stick my neck out—you will not have a direct replacement. That is not the way the world works. HDTV is different. It could very well be more expensive. It could be the consumer who will pay for it. It may cost a lot more money, it may have different effects, or it might cost less; we may put half of the television stations out of business because of this.

It is worth investigating. It is something that can be done, we do have the skills. I do not think it would take 6 months to figure out what it would cost to replace the current broadcasting industries. We do know something about econometrics; we can do an input/output analysis of the entire industry, for example.

Chairman GLENN. Let's start with a question following up on that then. Does that assume that we use the same transition network we use now, or do we go to a satellite system as Japan and our European colleagues are doing?

Mr. SOLOMON. Once we change some things, we change other things. This estimate is assuming everything is exactly the way it is now; I did not include what it would cost to upgrade the telecommunications network to do this. I did not think at all about what it would do to Hollywood. Roughly, it costs a billion dollars to replace a Hollywood lot. I have asked them quite often to give me some numbers on it and they get frightened when they think they may be forced to buy new Japanese equipment to make the same movies.

Chairman GLENN. Well, I think the overall cost of the transition to HDTV, if we are moving in this direction, is something we ought to look at and really consider carefully. What if I am a consumer someplace and we are moving to an HDTV transmission system and I do not want an engineering work station. I could not care less. I do not want to learn to run the thing. I only want to watch TV at home. I only want to watch "Roseanne" and "Cosby", and that is is all I want to do with an HDTV. And I want to see them as good as I can see them.

Now, am I going to have to pay a lot more to get my TV set and am I going to have to accept all the engineering work station features along with it that I do not want? What is the answer?

Mr. SOLOMON. No, I do not think that is the problem. I do not think it is going to cost much more to make a HDTV display as an engineering workstation, or vice versa. The HDTV display will have to have microchips in it. It will probably be more powerful than an engineering workstation in some respects, but it will not have the software.

Chairman GLENN. Who else would like to comment on that? Mr. McCloskey, you are going to be in the manufacturing of these things if we move into this. Can I get one without all the whistles and bells?

Mr. MCCLOSKEY. I think so. I think that is where the primary initial effort is going to be. There may be a merger of all these things sometime in the future, but the consumer electronics industry has focused for a long time on driving the price down and that will be the goal. So there will not be the dual system for the typical person who cannot even program his VCR now to worry about these other issues.

Chairman GLENN. Anybody else want to comment on that?

Dr. TIETJEN. I agree with that.

Chairman GLENN. Mr. Long? Yes.

Good. Mr. Long, you gave a figure in your testimony that indicated we are at a 25 to 30 percent cost disadvantage with Japan. You gave some reasons for that.

What is going to prevent that from being a difficulty in the future? I do not see that moving into HDTV is going to change that any. Are U.S. firms going to be able to make HDTVs in light of this 25 to 30 percent cost disadvantage?

Mr. LONG. I think you are exactly right, that cost disadvantage does exist. That is why manufacturing organizations are moving offshore—that and the low cost of foreign capital. You can acquire capital in the Far East, Korea or Japan at a much lower rate than you can here for these purposes. And somewhere along the line that is going to have to be addressed and fixed. And you often hear it is because of our deficit and low savings rate, but it is my understanding that the Japanese, on a GNP basis, have a higher deficit than we do. So I do not think that the deficit is entirely the issue.

Japan has an economy that focuses on the generation of capital for industry. As I indicated, consumer loans are very expensive there. They just do not allow anything to be used in the consumer sector in deference to the industrial sector.

Chairman GLENN. You all seem to feel that we are really sort of behind at this point on HDTV and that we need a jump start to get us going to catch up. But is there anything going on in the realm of leap-frogging this technology? What is the next step beyond HDTV? And is that what we should be spending our time and effort on, rather than playing catch up with HDTV?

Mr. TIETJEN. Well, I think within the realm of HDTV there are some leap-frog technologies to generate larger screen sizes, and I think some of the work that is going on sponsored through DARPA and other programs could, in fact, put us in a leadership position with regard to that kind of technology. Now, this is just exactly the kind of development that ultimately you might find working its way into other industries 10 or 20 years from today, but there are opportunities.

Chairman GLENN. Anybody else want to comment?

Mr. LONG. I would say that the large flat-panel screens are essential for HDTV. Basically the reason is if you build a CRT that large you cannot even get it through a door, and you cannot lift it. So it is impractical to carry CRT technology into those sizes. So it will have to be flat screens. This is one example of the opportunities we are talking about. We are asking for funding for DARPA and NIST to help industry develop these products. But somewhere along the line you are going to have to face up to the fact that $300 million, $400 million, or $500 million will be needed to build a manufacturing plant and the cost of capital becomes an issue again.

If money is available in Japan for the Japanese to put a plant in place at anywhere from 0 to 4 percent interest, you can bet that is where it is going to be done rather than in the United States at 11 plus percent interest.

The economics just dictate that that is where the business of manufacturing is going to go if we do not do something about it.

Chairman GLENN. But do you see the flat-panel display as being a significant technology driver? Is that sort of key to the whole thing?

Mr. LONG. It is a very key item. Another key item is that data rates in your receiver will be in the neighborhood of 1.3 gigabits. This will most likely be compressed to be transmitted over fiber, and certainly fully compressed to be transmitted over the air.

As a matter of fact, I do not think that we will ever derive the full benefits of HDTV by broadcasting it over the air. I think it is going to have to be transmitted by fiber and that is ultimately the best way to do it.

Chairman GLENN. What about satellites?

Mr. LONG. Satellites could be used. Again, that is going to be very expensive. Every household will need a receiver to receive the satellite signal, and that will not come cheap.

Chairman GLENN. Your comment on the bulk brings up a different line of thought. An argument has been made that because HDTVs will probably be bulky products, they are more likely to be assembled here, whether they are assembled by Zenith, Sony USA, or others.

How will this U.S. location of HDTV production, if it occurs that way, going to affect the demand for U.S. produced semiconductors?

Mr. MCCLOSKEY. Gives them an opportunity.

Ms. HUBBARD. I think it gives them an opportunity, but I would not want to bank my future growth on it if I were a U.S. semiconductor manufacturer. Foreign owned, no matter where they are based, historically tend to source their electronic componentry from their home market. So just producing tubes, glass, wire, wood sets is not really the issue here. It is where the electronic componentry that drives those sets comes from.

Currently, 6 percent of U.S. semiconductor units are used in consumer electronics worldwide, while 50 percent of Japanese semiconductor units go into consumer electronics. We do not see anything that is going to change that unless, again, there is some incentive from the U.S. side to purchase U.S. semiconductors.

Might I just add, in reference to new applications, that other than flat-panel displays, there is the chip-on-glass technology, which has a variety of defense and civilian applications. So there are lots of issues here that just cannot be discussed briefly.

Chairman GLENN. Well, that chip-on-glass technology, won't that soon be available in small portable computers? I understand some use of that is going to be made in the near future; is that correct?

Ms. HUBBARD. I certainly think one of our companies is counting on that, but I think the real application is going to the larger screens.

Mr. McCLOSKEY. Senator, I would like to add something, though. I think we have minimized, perhaps, too much this tube technology in talking about chips and glass and wire and whatnot. We are talking about 50 percent of the manufacturing cost of the set, so we are really talking about a very significant portion. In the electronics we are talking 10 to 15 percent of the cost of the set.

So it is much smaller. So in terms of jobs, we are really talking about more jobs from the fact that the tubes would be manufactured here. And I think the opportunity that exists is in this display area. If we ever get to light valves and liquid crystal displays of the size that meet brightness and the color and all of that, then there is that opportunity for U.S. companies. And there are some U.S. companies who believe that they are ahead.

And if indeed they are ahead, they are going to corner a market. And I think that is a very good place for funding by DARPA, a very good place for consortiums to operate. But the tube industry—the tube that the gentleman from MIT mentioned, the Sony tube is being made in the United States for the FAA application. It is a very important technology driver. Much of the development was done in the United States for that.

That is twice the definitional clarity of HDTV. It is 2,048 lines as opposed to the roughly 1,000 lines that we are talking about.

Mr. LONG. Mr. Chairman, we have a joint venture with Sony and so I know quite a bit about what goes on at Sony. The tube was developed in the United States. It was made in Japan, it is made in Japan. They have a plant in San Diego but all the parts come from Japan, the glass is even sourced in Japan. So they were assembled in San Diego.

I do not know about the other CRT manufacturing in the United States, but I do know Sony's operations very well.

Chairman GLENN. What transmission standards and techniques are we going to use. The Japanese and the Europeans are on a different tack than we are. Are we going to harmonize with them or not?

What do you recommend in this area?

Mr. SOLOMON. I think that that is one of the key areas. I agree fully with the previous panelists that flat-panel displays and others are a major market. But one thing we are very good at in the United States is computers, and we should capitalize on our strengths. We can do things with transmission because of our skills in computation, software as well as hardware, that the Japanese and the Europeans seem to have avoided so far.

I do not agree completely that fiber is the only way to go, and I happen to be a very strong proponent of fiber optics for the United States. I think fiber is eventually going to happen. It is a major construction program, so it is going to take 10 or 15 years, and it should be done, and we should start now. But, I think there will be an interim system and there will always be a need for over-the-air television transmission. We can do a lot by developing, as Dr. Tietjen said earlier, a standard for over-the-air transmission for HDTV, or better, one that has links to the future, one that we could sell to the rest of the world. Because the Europeans and Japanese are not doing it, yet.

The others, in a way, copped out and used satellite technology. And I will tell you why the Europeans did it, I don't know why the Japanese did it. The Europeans were planning to put up some satellites that simply didn't have enough demand for business services. With the European aerospace interests, they realized that they could fill it perhaps with HDTV at first.

If they are wrong—and I have heard this directly from the people that designed it—they still have the satellites up for business purposes, they don't care whether HDTV succeeds or not. This was sort of a filler.

But as a result, they have not done much work on over-the-air transmission. They have not yet done much work on fiber and coaxial cable transmission. These are tricky areas that the United States is perhaps on a level playing field with the others. But if we do not do something soon, we will be behind again.

Chairman Glenn. What do you estimate the cost of an HDTV set will be? Let's say I just want my television set, as I said awhile ago. Let's say all I want to do is go home and watch high resolution television.

What can I buy a set for?

Mr. Solomon. What are you willing to buy the set for? If you are willing to spend $10,000, there are some firms right now that will sell it to you. But are you willing to spend that?

Chairman Glenn. What I am trying to get at is some idea as to how willing the American public is going to be to rush out and buy HDTVs, because you need that kind of support if we are going to make all these expenditures for stations and conversions, and it is going to occur over a period of time. We know that color TV didn't really take off until color programs were widely available, which means there had to be some up-front costs that were recouped later. And we are talking about billions of dollars here. It is not going to come easy.

We can support the research in these areas perhaps, but I doubt that we are going to be willing as a Government to move into subsidizing all the stations and new transmission, whether it is satellite or fiber optics or whatever it is. That is not likely to be subsidized. So the infrastructure is going to have to support itself some way.

How expensive are the first sets going to be?

Mr. Solomon. Our research showed that there wasn't much excitement for the existing HDTV sets, which were 28 inches and 18 inches, that we ran parallel with the standard, very high quality studio NTSC monitor.

Chairman **Glenn**. That was looking at them as TVs, not as engineering workstations?

Mr. **Solomon**. Oh, well, looking at them as workstations would be a different market. For the workstation market, it is clear people will spend a lot of money. Look at the FAA.

Chairman **Glenn**. Well, we are going to have to end the hearing. I appreciate all of you being here. I have another commitment. I do want to note two things.

Our low member attendance this morning is because we have several members of the Committee involved in the Hastings trial and they are tied up from 9 to 5 every day on that. Also, the Department of Defense authorization bill is on the floor, which is where I should have been all morning also, because I am on the Armed Services Committee. We have a number of people from this Committee involved with that as well.

I want to close by saying that I think this hearing has been a good discussion about HDTV policy. I hope that it is a trigger for additional discussion. As to whether CBO threw a wide enough loop to catch everything that everybody wanted to have discussed in one report is, obviously, a question mark. But I do hope the report and this hearing will galvanize the public's perception that HDTV means far more than just TV. I think that will be very helpful to us as we continue this debate.

I am sure we will have more hearings on this at a later date. We appreciate you all being here this morning. Thank you, and the hearing will stand in recess subject to the call of the Chair.

[Whereupon, at 12:05 p.m., the hearing was adjourned subject to the call of the Chair.]

APPENDIX

Statement of
Robert D. Reischauer
Director
Congressional Budget Office

before the
Committee on Governmental Affairs
United States Senate

August 1, 1989

NOTICE

This statement is not available for public release until it is delivered at 9:30 a.m. (EDT), Tuesday, August 1, 1989.

Mr. Chairman and Members of the Committee, I appreciate the opportunity to present the Congressional Budget Office's (CBO's) analysis of the major private forecasts of the market for high-definition television (HDTV) receivers and its potential effects on the economy. The report we are releasing today was undertaken at the request of the Committee. It is an interim step toward a fuller analysis of proposed industry research consortia in the areas of HDTV, X-ray lithography, and dynamic random access memories. I want to emphasize that the scope of this interim study is limited to an examination of the economic assumptions that underlie the private market forecasts. CBO's final report will address many of the broader questions concerning the federal role in this area that are not dealt with in the current report. This interim report seeks to answer two questions:

- Will there be a large market for HDTV receivers; and
- Is this market crucial to the competitiveness of the U.S. electronics sector?

In answer to the first question, CBO finds the forecasts very optimistic about market size and certainly about timing, although some consumer products have enjoyed the level of success projected for HDTV. With regard to the second question, it is unlikely that HDTV will by itself revitalize the U.S. electronics sector. According to even the optimistic forecasts, the HDTV market is small relative to other electronic equipment markets.

BACKGROUND

Concerns about the competitiveness of U.S. industry have prompted Congressional proposals for additional federal support to increase the rate at which U.S. firms bring new technology to market. Proponents of such incentives argue that because federal agencies do not now provide much support for technologies that are near commercial development, certain U.S. industries are at a disadvantage relative to industries in countries that do provide such aid. The erosion of the international market share of several U.S. high-technology industries is interpreted as evidence of this problem. One potential new product receiving a lot of attention as a candidate for such incentives is HDTV--a term referring to television receivers with new technology that will combine computers and conventional television technology.

The desire for U.S.-based firms to have a substantial share of the HDTV market has produced a range of policy proposals that vary in size and scope. At one end, the Defense Advanced Research Projects Agency (DARPA) already has allocated $30 million over the next three years for research that relates to the HDTV display, primarily flat-panel screens. At the other end of the spectrum, the American Electronics Association has proposed a package of federal support for HDTV that would include $1.0 billion in loans and loan guarantees for manufacturing facilities, $300 million over three years to expand DARPA's HDTV research, and $50 million to develop standards.

Advocates of federal support for HDTV view it as part of a broad strategy to revitalize the U.S. electronics sector. They have different views, however, of the directions federal policies should take. Some would argue for a federal role in the development and manufacturing of consumer products. Others would like to see federal policy support the development of low-cost, high-resolution digital techniques to create images for uses in medicine, scientific instruments, and computing, as well as for consumer products. In this latter view, the consumer uses are not necessarily either the first or the most likely to find a large market.

MARKET SIZE

CBO's analysis of the private market forecasts began by asking whether the available evidence supported the forecasts of a large market for HDTV receivers. This evidence convinced us that these forecasts seem to be at the high end of the range of the industry's likely sales. No one can foresee with great confidence how successful HDTV will be. The success predicted by private market forecasts may be justified by the large price differentials consumers have paid for color television over monochrome, and by the recent rapid growth of the market for premium television receivers. Whether consumers will value the incremental benefits of HDTV as highly, however, is not clear, especially if there are intermediate and cheaper types of advanced television to choose from. Evidence from consumer surveys suggests that viewers' preferences for HDTV vary with the program's subject matter, viewers' distance from the set, and other factors (including the picture quality of alternative standard TV sets).

The near-term success of HDTV most likely will depend on how it is brought into the consumer marketplace and on other variables that the market studies have not addressed. As has been shown in product after product, consumers place emphasis on features usually unforeseen by the "experts." The introduction of high-technology consumer products is usually followed by a lengthy trial period in which consumers, producers, and providers of ancillary services grope toward a definition of the product. By contrast, the market forecasts reviewed in this report see HDTV as successful from the start--an event that eluded some of today's most popular consumer electronics products, such as video cassette recorders (VCRs) and microwave ovens. Thus, some skepticism about the timing, if not the eventual size, of HDTV's market success seems warranted.

COMPETITIVENESS IN OTHER ELECTRONIC PRODUCTS

As to the second question--Have the studies shown that the market for HDTV receivers is crucial to the competitiveness of the U.S. electronics sector?--the answer seems clearer. In evaluating the claims for HDTV made in the forecasts, CBO has found that either the markets are unlikely to be big enough to have the hoped for effects, or the sequence of events asserted by the studies is not sufficiently developed to warrant the conclusions drawn. Even the optimistic forecasts of the potential size of the HDTV market are small relative to the other markets in the electronics sector. Thus, it is hard to believe that HDTV will by itself play a pivotal role in the competitiveness and technology development of the sector as a whole. U.S.-based electronics manufacturing firms may gain or lose market share in the next 20 years, but they already have many incentives to maintain their competitiveness and a large enough market in which to enjoy economies of scale.

Exactly how the HDTV market would change the competitiveness of U.S. producers is unclear. The entire world market for electronic equipment grew by $54 billion in 1988 to reach $461 billion. The world market for HDTV receivers and VCRs is forecast to be less than $30 billion (in 1988 dollars) by the year 2010. It seems counterintuitive to suggest that such a small market that may exist in the future is a more important driver of economies of scale, technology, and competitive success than is the growth in the present market. It would be a case of the tail wagging the dog.

Even if the HDTV market reaches a substantial size, most HDTV receivers would probably be produced in the United States regardless of whether foreign- or domestic-based manufacturers become the dominant suppliers. Large receivers are produced in the United States now primarily because of the bulk and fragility of many of the components, particularly the television tube and the cabinet. The possible introduction of flat-panel televisions at the premium end of the market, however, might reduce the U.S. manufactured content somewhat because these panels may be easier to import. But, even if domestic firms become the dominant suppliers, some HDTV components (semiconductors in particular) probably would be imported; for example, U.S. firms dominate the personal computer market while buying many of their semiconductors from abroad.

Advocates make a case for supporting HDTV on the grounds that it will improve the competitiveness of the electronics sector. They believe that certain HDTV technologies will serve as "technology drivers" for the rest of the electronics sector and that a network of common technology and components make the knowledge gained in HDTV useful in other major electronic goods. But these advocates have presented little concrete evidence for this belief. While they have made strong claims for the importance of HDTV to continued U.S. leadership in electronics technology, these strong claims have not yet been backed up with strong evidence.

Stating that HDTV will contain high-technology components is not enough. Outside of display and imaging technology, HDTV technology is not unique. For example, the memory chips in HDTV are widely used in other products, so the contribution of HDTV to that market is likely to be marginal. Even the display and imaging technology is not unique to HDTV receivers: producers of computer workstations and others already use high-resolution displays. U.S. computer firms continue to advance their strong positions in the markets for workstations and high-resolution imaging through R&D and other investments. Consequently, it is not at all clear that consumer products will drive or significantly spur advances in this technology. Furthermore, pushing already successful electronics companies into markets (such as consumer electronics) in which they are not naturally positioned may not serve the interests of U.S. competitiveness.

CONCLUSIONS

These conclusions do not necessarily mean that federal support for HDTV development is without merit. Support for HDTV might be justified for reasons other than competitiveness in the electronics sector--for instance, employment, national prestige, or scientific advancement. The Defense Advanced Research Projects Agency is pursuing HDTV-related technologies, primarily flat-panel display screens and digital imaging technology, for possible military applications. In addition, development of the HDTV market, although small on its own, might also have a role to play in a broader strategy for government involvement in the U.S. electronics sector, including attempts to create a U.S. industry manufacturing a whole range of consumer electronics.

Finally, the desire to foster HDTV development in the United States comes from the very laudable motive to reduce the trade deficit. That trade deficit exists, not because of a sudden loss of technological leadership, but because the U.S. economy is saving too little and absorbing too many resources for current consumption relative to U.S. production. As a result, there is a more direct route to reducing the trade deficit: decrease the budget deficit and thereby raise national saving. Discussing the programs that might be cut and the taxes that might be increased are more pertinent than conjectures about the technology of the next century.

My remarks today are not meant to foreclose the possibility that greater public intervention to foster U.S. competitiveness may be warranted. The list of possible intercessions is long, however. The Congress therefore should demand that proponents of aid to one or another industry provide convincing evidence of why their particular industry deserves preferential treatment.

Question 1: **WITNESSES AT THE HEARING IN THE PANELS FOLLOWING YOUR TESTIMONY COMMENTED ON THE CBO REPORT. PLEASE DISCUSS WHAT YOU FEEL WERE THE MOST SALIENT OF THEIR REMARKS.**

The hearing produced an agreement among the witnesses that the narrow definition that equated high-definition television (HDTV) with a fancier television receiver was incorrect; all agreed on a broader definition of HDTV to encompass high-resolution digital imaging technology. CBO does not disagree. Indeed, our report points out that the computer and workstation industry is likely to commercialize high-resolution digital imaging technology long before consumer applications become widespread. But the private market forecasts that we were asked to evaluate all focus exclusively on HDTV as television receivers. In retrospect, we might have been clearer about distinguishing our own view of HDTV as an emerging technology with potentially broad applications in industry and government, from the private forecasts' view of HDTV as a consumer electronics product for the home.

The appropriate definition of HDTV is an important point, particularly when considering possible government strategies and options. If computer and industrial applications of the technology become widespread before consumer applications, then consumer applications are not likely to be the engines that move high-resolution digital imaging technology forward. And, as noted at the hearing, many computer display systems already have a density similar to HDTV (over 1,000 lines per screen). Even in the personal computer market, several U.S. semiconductor and computer companies are currently competing to have their graphics system adopted as the "industry standard" around which software and other applications would be designed. Consumer applications may make some technological advances, most likely in the area of cost reduction, but these contributions are likely to be proportional to the size of the consumer market relative to the overall market--that is, not large. If computers, not consumer products, are likely to move the technology forward, then one might spend federal funds differently than if manufacturing consumer products were at the heart of technological progress.

A distinction should be made between technology and products. There was substantial agreement among the expert witnesses at the hearing that HDTV technology would be important in a variety of products. Although the reports that CBO was asked to review make broad claims for the importance of the consumer product, the industry itself now seems to be shifting the focus of its interest in HDTV away from consumer products and toward more commercial uses of the technology. We have not yet looked at the broader questions of technology.

Response to the MIT Media Laboratory

The testimony by the Media Laboratory of the Massachusetts Institute of Technology (MIT) suggested that CBO had misread the MIT study on consumer attitudes toward HDTV. The testimony argued that rather than being a general finding, the Media Lab's finding was very narrow--that consumers do not particularly like the HDTV system developed by the Japanese. Since the Japanese system is the only complete HDTV system currently available on the market, not liking Japanese HDTV means not liking HDTV for now. More importantly, if the MIT findings indeed are as the testimony suggests--that consumers do not really like the Japanese HDTV system--then even though the Japanese have spent almost $1 billion on HDTV, they have clearly failed to produce a commercially viable system. If this is true, then the assertion that other nations are "ahead" of the United States in HDTV must be substantially discounted.

Response to the American Electronics Association

The American Electronics Association (AEA) argued that theirs was a "working" document, more indicative of the type of economic effects of HDTV than a detailed econometric analysis. However, CBO's critique of the AEA analysis was not based on minor methodological issues. Quite the contrary, CBO's disagreement is with the major assumptions and overall tenor of AEA's conclusions, principally their unsubstantiated assertion that small consumer markets are more crucial to the competitive success of U.S. electronics firms than are the actions of those same firms in the markets where they currently hold dominant positions.

Response to the Defense Advanced Research Projects Agency (DARPA)

While it has become clear that flat-panel technology is crucial to HDTV, it is not clear that HDTV is crucial to flat-panel technology. The DARPA representative testified on the many uses other than HDTV to which flat panels might be put, suggesting that such displays might even replace the dashboards on cars, not to mention the possible military and instrumentation uses. As noted in CBO's report, millions of flat-panel displays are already sold every year for laptop computers and portable conventional television receivers.

Question 2: WOULD ANY OF THE CRITICISMS OF THE CBO REPORT CAUSE YOU TO CHANGE OR REVISE YOUR CONCLUSIONS?

As mentioned above, the HDTV report written by CBO could have been clearer about how rapidly computers are already adopting high-resolution digital imaging technology. This lack of clarity may be one reason why the CBO report was viewed as being too narrowly focused and ignoring the larger uses of the technology. Another reason may be that the report analyzes market forecasts that, at least in the case of AEA, are now somewhat dated. Recent discussions among HDTV advocates have been downplaying the consumer uses of high-resolution digital imaging technology while stressing the federal role in sponsoring the computer and industrial uses of this technology. The considerable doubts that have been raised as to the size and significance of the consumer HDTV receiver market may lead to questioning the wisdom of using federal funds to support the manufacturing of such TV sets. This is not to suggest that funding for developing more broadly applicable signal processing or display technology is inappropriate, but CBO is not in a position to judge what level of funding for such R&D (the range of $50 million to $100 million per year is now under discussion) is appropriate.

In its final report, CBO will emphasize that high-resolution digital imaging technology is already being used in computers and that this trend seems likely to accelerate long before significant consumer uses develop. However, this emphasis should be viewed as a clarification, not a change in CBO's analysis. Nothing said at the hearing by other witnesses would cause us to change our analysis of HDTV, viewed as a consumer elctronics product for the home. CBO reaffirms its view on the reports it was asked to analyze. The reports are optimistic about the size and certainly the timing of the market for consumer HDTV receivers. More importantly, the assertions that HDTV receivers are crucial to the continued competitiveness of the U.S. electronics sector remain unproved and out of line with the size of even the optimistic HDTV market forecasts.

STAFF WORKING PAPERS

THE SCOPE OF THE HIGH-DEFINITION TELEVISION MARKET AND ITS IMPLICATIONS FOR COMPETITIVENESS

JULY 1989

NOTICE

This report is not available for public release until 9:30 a.m. (EDT), Tuesday, August 1, 1989.

CONGRESSIONAL BUDGET OFFICE
SECOND AND D STREETS, S.W.
WASHINGTON, D.C. 20515

PREFACE

This Congressional Budget Office (CBO) staff working paper analyzes major private forecasts of the market for high-definition television (HDTV). The study is an interim report, requested by the Senate Committee on Governmental Affairs, on work in progress in response to an earlier request from that Committee and the Senate Budget Committee. It analyzes the economic assumptions that underlie widely used forecasts of the HDTV market, and evaluates the implications and soundness of these forecasts. The final report will analyze the possible use of federal funds to support industry consortia, such as the one proposed for HDTV. In keeping with CBO's mandate to provide nonpartisan analysis, this report makes no recommendations.

Philip C. Webre of CBO's Natural Resources and Commerce Division wrote the paper under the supervision of W. David Montgomery and Elliot Schwartz. The staffs of the Electronic Industries Association and American Electronics Association provided valuable comments and assistance. The author would like to thank Michael Aisenberg, Samuel Baldwin, William Bandy, Fredrick Branfman, Marshall Butler, Robert Cohen, David De Voe, Grant Dove, Craig Fields, Peter Friedman, Jeff Hart, Suzanne Heaton, Patricia Hill Hubbard, Daniel Kaplan, Thomas Long, David Moore, Lane Pierrot, Dorothy Robyn, Ronald Rosenzweig, Marko Slusarczuk, David Staelin, Robin Whiskin, and Sarah Williams for their comments on the earlier drafts. Thomas Lutton provided statistical assistance. Kathryn Quattrone prepared the figures. Sherry Snyder edited the manuscript. Margaret Cromartie and Patricia Joy typed the many drafts, and Margaret Cromartie prepared the report for publication.

July 1989

CONTENTS

SUMMARY v

CHAPTER I INTRODUCTION 1

CHAPTER II THE MAJOR MARKET FORECASTS 5

- Summary and Comparisons of the Market Forecasts *6*
- Evaluation of the Forecasts *11*

CHAPTER III ECONOMIC EFFECTS OF HDTV ON RELATED INDUSTRIES 16

- Conclusions of the Market Studies *16*
- HDTV and the Competitiveness of the Electronics Sector *18*
- Conclusions *28*

BOX

1. Advanced Television Technologies 2

FIGURES

1. Projected Annual U.S. Unit Sales of High-Definition Television Receivers 7

2. Projected Annual U.S. Market Value of High-Definition Television Receivers and Related Video Cassette Recorders 9

3. Projected Price of High-Definition Television Receivers 10

4. AEA Forecast of World Sales of Semiconductors 22

SUMMARY

Some analysts believe that high-definition television (HDTV) will be the next major successful consumer electronics product. At stake are both the market for HDTV products themselves and the markets for electronic inputs--in particular, semiconductors--and other associated electronic goods. The belief that HDTV will be a very important market has led to a wide range of proposals that federal agencies provide support for the development of HDTV capability among U.S. firms. This report analyzes three major private forecasts of the market for HDTV and asks two questions:

- Will there be a large market for HDTV sets? and
- Is this market critical to the competitiveness of the U.S. electronics sector?

The answer to the first question depends on many variables. The three market studies analyzed here seem to be at the high range of the industry's likely sales. The answer to the second seems clearer: even the most optimistic market growth would be unlikely to affect other electronics industries in the way suggested by proponents of HDTV. In reviewing the claims for HDTV made in the market forecasts, CBO found in general that either the markets were unlikely to be big enough to have the hoped for effects, or the sequences of events asserted by the studies were not sufficiently developed to warrant the conclusions drawn.

MARKET SIZE

No one can foresee how successful HDTV will be. The success predicted by private market forecasts may be justified by the large price differentials consumers have paid for color television over monochrome, and by the recent rapid growth of the premium television receiver market. Whether consumers will value the incremental benefits of HDTV as highly, however, is not clear, especially if there were intermediate types of advanced television to choose from. Evidence from consumer surveys suggest that viewers' preferences for HDTV vary with the program's subject matter, distance from the set, and other factors (including the picture quality of alternative standard TV sets).

The success of HDTV in the shorter term most likely will depend on how it is brought into the consumer marketplace and on other variables that the market studies have not addressed. As has been shown in product after product, consumers place emphasis on features usually unforeseen by the "experts." The introduction of high-technology consumer products is usually followed by a lengthy trial period in which consumers, producers, and providers of ancillary services such as retailers grope toward a definition of the product. By contrast, the market forecasts reviewed in this report see HDTV as an instant success--an event that eluded some of today's most popular consumer electronics products, such as video cassette recorders (VCRs) and microwave ovens. Thus, some skepticism about the timing, if not the size, of HDTV's eventual market success seems warranted.

COMPETITIVENESS IN OTHER ELECTRONICS PRODUCTS

The likely effect of HDTV on other electronics markets seems clearer. If the HDTV market reaches a substantial size, most HDTV receivers would probably be produced in the United States regardless of whether foreign- or domestic-based manufacturers become the dominant suppliers, although the possible introduction of flat-panel televisions at the premium end of the market might reduce the U.S. manufactured content somewhat. Receivers are produced in the United States primarily because of the bulk and fragility of many of the components, particularly the television tube and the cabinet. However, even if domestic firms become the dominant suppliers, some components (semiconductors in particular) probably would be imported. U.S. firms dominate the personal computer market while buying many of their semiconductors from abroad.

Even the optimistic forecasts of the potential size of the HDTV market are small relative to the other markets in the electronics sector. Thus, it is unlikely that HDTV will play a pivotal role in the competitiveness and technology development of the sector as a whole. U.S.-based electronics manufacturing firms may gain or lose market share in the next 20 years, but they already have many incentives to maintain their competitiveness and a large enough market in which to enjoy economies of scale. Exactly how the HDTV market would change the competitiveness of U.S. producers on the whole is unclear. The entire world market for electronic equipment grew by $54 billion in 1988 to reach $461 billion. The world market for HDTV receivers and VCRs is forecast to be less than $30 billion (in 1988 dollars) by the year 2010. It seems counterintuitive to suggest that a small market that may exist in the future is a more important driver of economies of scale, technology, and competitive success than is the growth in the present market.

These conclusions do not necessarily mean that federal support for HDTV development is without merit. Support for HDTV might be justified for reasons other than competitiveness in the electronics sector--for instance, employment, national prestige, or scientific advancement. The Defense Advanced Research Projects Agency is pursuing HDTV-related technologies, primarily flat-panel display screens and digital imaging technology, for possible use in military applications. In addition, HDTV development, although small on its own, might also have a role to play in a broader strategy for government involvement in the U.S. electronics sector, including attempts to create a U.S. industry manufacturing the whole range of consumer electronics.

CHAPTER I

INTRODUCTION

Concerns about the competitiveness of U.S. industry have prompted Congressional proposals for additional federal support to increase the rate at which U.S. firms bring new technology to market. Proponents of such incentives argue that because federal agencies do not now provide much support for technologies that are near commercial development, certain U.S. industries are at a commercial disadvantage relative to industries in countries that provide such aid. The erosion of the international market share of several U.S. high-technology industries is interpreted as evidence of this problem.

One potential new product receiving a great deal of attention as a candidate for such incentives is high-definition television (HDTV)--a term referring to television receivers with new technology that will combine computers and conventional television technology (see Box 1). To provide truly enhanced television pictures, more information will have to be transmitted, stored, processed, and displayed on a screen. As a consequence, the components of these new sets may be closer to those of an engineering workstation or personal computer than to the current generation of television receivers. The components that have received the most attention include semiconductors--most notably memory chips and digital signal processing devices--and flat-panel display screens.

Spurred in part by the recent success of foreign manufacturers of consumer electronic goods, such as the video cassette recorder (VCR) and the audio compact disk player, proponents of federal support for commercializing new technology argue that without a substantial U.S. presence in the market for HDTV receivers, U.S. electronics firms and related manufacturers will be handicapped relative to foreign firms, which will come to dominate these large markets. Thus, the competitive arena is the combined markets for HDTV receivers, the components for those receivers, and other electronic products that also use these components.

Supporters of federal assistance are concerned that U.S.-based manufacturers be among the initial suppliers of HDTV sets for the commercial market. The rationale offered for federal support is that the firms that initially gain a substantial portion of the HDTV market will subsequently be able to reduce their costs through economies of scale and associated learning curve advantages. Such cost reductions will give the initial market winners a competitive advantage not only in the HDTV market, but also in supplier and associated electronics markets (such as the semiconductor and personal computer markets).

Box 1

ADVANCED TELEVISION TECHNOLOGIES

The current debate over high-definition television (HDTV) has created a great deal of confusion over the meaning of commonly used terms. The studies discussed in this report each use terms common to the debate differently. Sometimes different terms refer to the same technology, while other times the same word refers to different technologies. The definitions of the technologies, as used in this report, are given below. They should not be considered precise definitions, partly because the technology and standards have not yet been set. Rather, these definitions can be viewed as "center of gravity" ideas, around which proposals for hardware standards are currently fluctuating.

The three new varieties of advanced television (ATV) that are usually discussed by engineers include: improved-definition (IDTV), enhanced- (or extended-) definition (EDTV), and high-definition. As the names suggest, each represents a successive generation of improved television technology. In this sense, they are like personal computers, where IBM-compatible personal computers were first developed with XT-compatible models, then with AT-compatible models, and most recently with 386-compatible models, each upwardly compatible with the same software. Under current Federal Communications Commission regulations, programs to be shown on ATV systems must be able to be viewed on receivers built for the current color television standard, also known as National Television Standards Committee (NTSC) technology. When programs are broadcast for ATV, however, viewers using NTSC receivers may not see as much as viewers watching on more advanced sets. This report focuses on high-definition television, not all forms of advanced television.

Improved-definition television. IDTV receivers have come on the market in 1989. This system requires no change in broadcast equipment or bandwidth, being mainly an improvement in receiver technology. In IDTV, the signal received is digitized, processed, stored in memory as a frame, and then displayed roughly 60 times per second. These receivers have a relatively small amount of memory (roughly 8 million bits) and other semiconductors for storage and digital signal processing. The screen looks like a conventional television screen.

Enhanced-definition television. EDTV receivers are expected in the U.S. market within the next half decade. The number of lines per television screen may be increased somewhat from the NTSC standard of 525 lines. In addition, the ratio of width to height of the television screen, currently 4 to 3, may be shifted to 15 or 16 to 9, making it closer to movie screen ratios. However, this would be accomplished within the current broadcasting bandwidth of 6 megahertz and by using much of the same broadcast equipment. The receivers would need more memory and digital signal processing than the IDTV to accommodate the same information, but would basically be a larger and faster version of the same device.

High-definition television. HDTV receivers would be introduced sometime after EDTV. They would be very similar to EDTV and IDTV, but the number of lines would be double the current U.S. standard, or between 1,050 and 1,260. They would have a movie screen-like ratio of width to height and digital-quality sound. Consequently, each frame would have roughly four times the information of the current television screen. For this reason, it would need roughly four times the memory of IDTV (or roughly 4 million bytes, or 32 million bits, of memory) and correspondingly more digital signal processing. In addition, HDTV would require new production and broadcast equipment as well as a greater allocation of the broadcast spectrum.

The desire for U.S.-based firms to have a substantial share of the HDTV market has produced a whole range of policy proposals. At one end, the Defense Advanced Research Projects Agency (DARPA) already has allocated $30 million over the next three years for research into technologies that relate to the HDTV display, primarily flat-panel screens, with potential military use. At the other end, the American Electronics Association (AEA) has proposed a package of federal support for HDTV that would include $1.0 billion in loans and loan guarantees for manufacturing facilities, $300 million over three years to expand DARPA's HDTV research, and $50 million to develop standards.[1]

These proposals reflect the divergence of views regarding HDTV. A more narrow definition of HDTV equates it with advanced-technology television receivers. A more expansive definition of HDTV, however, refers to the development and widespread use of low-cost, high-resolution digital techniques to create images for uses in medicine, scientific instruments, computing, and consumer products. In this broader definition, the consumer uses are not necessarily either the first or the most likely use to find a mass market.

The policy prescriptions following this divergence of views also differ. The narrower view of HDTV centers on the success of U.S.-based firms in manufacturing and selling television receivers. Consequently, the bulk of the federal financial support in the AEA proposal is devoted to manufacturing. By contrast, the DARPA request would develop generic technologies that would find widespread use in imaging products.

Both proposals share a common belief that, rather than compete directly with foreign electronics firms, U.S. electronics firms should preempt them by creating newer and better products, including consumer electronic products, and so increase the share of world electronics markets held by U.S.-based firms. In both proposals, HDTV--however defined--has a role to play in this creation of and expansion into new markets.

Most advocates of HDTV development view this one technology policy as part of a broader, though not entirely articulated, policy of support for the U.S. electronics sector that the federal government must undertake in order to restore that sector to full competitiveness. Not all programs are new: some, like Sematech, a semiconductor research and development (R&D) consortium, are already under way; in other instances, the goal is to reorder spending priorities within existing technology development programs. Although there is no agreement on the particular constellation of programs, most advocates feel that if the federal government pursues only HDTV and disregards other electronics markets, the position of U.S. firms will not be enhanced. On the other hand, if the government supports the full menu of programs, federal support of HDTV may contribute only marginally to the competitiveness of the U.S. electronics sector as a whole.

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[1] American Electronics Association, "Background Information: Development of a U.S.-Based ATV Industry" (Santa Clara, Calif., May 9, 1989).

Part of the debate over federal participation in the development of HDTV focuses on the size of the market for HDTV sets and the importance of this market to the competitiveness of other U.S. electronics industries. Other aspects of the policy debate, including employment, scientific potential, national prestige, and possible federal uses of HDTV-related technologies, are also likely to weigh in the Congress' consideration. In this report, however, the Congressional Budget Office (CBO) focuses on the narrower issues of HDTV's market size and contribution to competitiveness and on the major HDTV market forecasts, assessing their potential economic implications and the validity of their assumptions and conclusions. The broader question of whether the public benefits from HDTV are sufficient to warrant a federal role is not addressed in this report.[2]

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[2] This issue is taken up in the forthcoming CBO report, Federal Support for R&D Consortia.

CHAPTER II

THE MAJOR MARKET FORECASTS

Discussions of U.S. policy toward high-definition television focus on three market forecasts of HDTV sales. All predict that HDTV receivers will be available to consumers in the early 1990s and that programming for HDTV will begin shortly thereafter. The following summarizes the three market forecasts:

- The National Telecommunications and Information Administration (NTIA) commissioned a report, commonly known as the Darby report, which examines the growth patterns in sales of previous consumer electronic products and forecasts the growth of HDTV.[3] The Darby report differs from the others in that it has both low-growth and high-growth scenarios. It forecasts sales of HDTV receivers and video cassette recorders (VCRs) for the years 1997 through 2008. It concludes that if HDTV replicates the growth pattern of color televisions and VCRs, the market could expand rapidly to achieve annual sales of 18.6 million units by the year 2008.

- The Electronic Industries Association (EIA), a trade association that represents all electronics companies in the United States (whether foreign- or U.S.-based), commissioned a study of the HDTV market. That study predicts how the projected demand for HDTV will affect U.S. employment and overall economic activity.[4] Unlike the other two reports, the EIA forecast, which covers the period 1989 through 2003, excludes VCRs for HDTV. The EIA report concludes that sales of HDTV could reach 13.1 million units by 2003, raising income and employment in the electronics sector, regardless of whether the market is supplied by foreign- or domestic-based producers.

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[3] Department of Commerce, National Telecommunications and Information Administration, "Economic Potential of Advanced Television Products" (prepared for NTIA by Darby Associates, Washington, D.C., April 7, 1988), referred to hereafter as the Darby report. Even though the report discusses all advanced television products and makes no distinctions in the text, the author has told CBO that the scenarios are for HDTV.

[4] Electronic Industries Association, "Television Manufacturing in the United States: Economic Contributions--Past, Present, and Future" (produced under contract by Robert R. Nathan Associates, Washington, D.C., February 1989), referred to hereafter as the EIA report.

- The American Electronics Association (AEA), a trade association--which, in the area of HDTV, represents U.S.-based firms--is mainly concerned with how demand for HDTV could affect the competitiveness of U.S. high-technology industries.[5] The AEA forecast for both HDTV receivers and VCRs (and affiliated industries) covers the period 1990 through 2010. The AEA report forecasts sales of 11 million units by 2010 and concludes that unless 50 percent of the U.S. HDTV market is supplied by U.S.-based firms, the market shares of U.S. producers in other industries, most notably semiconductors and personal computers, will decline substantially.

One problem with any analysis of competitiveness is the definition of the nationality of firms and the products they make. Most analyses characterize the nationality of a firm by the nationality of its stockholders. This definition, however, ignores two important criteria: where production and where research and development (R&D) occur. It is not clear why a product made in Mexico by a firm owned by U.S. citizens is a U.S. product, while a product made in the United States by a firm owned by foreigners is a foreign product. R&D presents an equally vexing problem: while U.S. policymakers might want all firms to perform their R&D in the United States, many U.S.-based firms find it advantageous to perform their R&D in Japan or Europe. While recognizing these limitations, this report defines U.S.-based firms as firms owned by U.S. citizens, while foreign-based firms have foreign ownership.

SUMMARY AND COMPARISON OF THE MARKET FORECASTS

This section compares the forecasts in terms of annual unit sales, market value, and prices. Most data in the reports were presented in annual terms, but some data were given as cumulative figures. To facilitate analysis and comparison, CBO converted the cumulative data into yearly data. For example, a forecast of a market totaling $150 billion over the next 15 to 20 years will appear in this report as annual sales figures.

Unit Sales

The forecasts provide a range of market size and timing. Figure 1 compares the unit sales forecasts of the three reports. Darby's high-growth and the EIA forecasts see the market for HDTV sets becoming as large within the next 15 years as the market for color television sets was in the early 1980s (over 10 million units per year). EIA and AEA both see a market for HDTV as large as the current market for VCRs (11 million to 13 million units per year) within the next 15 to 20 years, with EIA being much more sanguine about HDTV's market growth.

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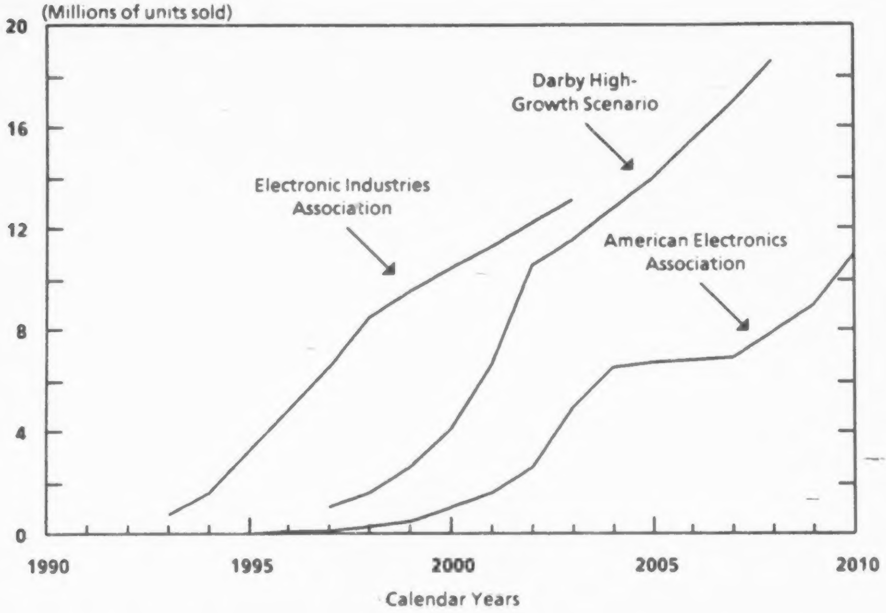
[5] American Electronics Association, "High Definition Television (HDTV): Economic Analysis of Impact" (prepared by the ATV Task Force Economic Impact Team of the AEA, Santa Clara, Calif., November 1988), referred to hereafter as the AEA report. The report also presents forecasts for the world HDTV market. CBO did not analyze that portion of the AEA forecast.

Figure 1.
Projected Annual U.S. Unit Sales of High-Definition Television Receivers



SOURCES: Congressional Budget Office based on data from the Electronic Industries Association, "Television Manufacturing in the United States: Economic Contributions--Past, Present, and Future" (produced under contract by Robert R. Nathan Associates, Washington, D.C., February 1989); Department of Commerce, National Telecommunications and Information Administration, "Economic Potential of Advanced Television Products" (prepared for NTIA by Darby Associates, April 7, 1988), referred to as the Darby report; American Electronics Association, "High Definition Television (HDTV): Economic Analysis of Impact" (prepared by the ATV Task Force Economic Impact Team of the AEA, Santa Clara, Calif., November 1988)

NOTE: The unit sales in the Darby low-growth scenario (not shown) are less than 150,000 per year.

Since color television and VCRs have been among the most successful consumer items introduced over the last several decades, these forecasts of HDTV sales are probably near the high end of the potential range of market size. By contrast, Darby's low-growth scenario illustrates what would happen if HDTV ended up serving only a specialized (or niche) market, such as that which projection television--which is most commonly found in commercial establishments rather than in private homes--serves today.[6] In this scenario, HDTV receiver sales would remain at the 100,000 to 150,000 unit level, less than half the current sales of projection television.

Market Value

All forecasts but Darby's low-growth scenario suggest that the market value of HDTV sales will grow rapidly. Figure 2 presents the sales forecasts of the three reports in 1988 dollars. The data include the sales of HDTV receivers and HDTV-related VCRs, except for the EIA forecast which excludes VCRs. Darby's high-growth scenario rises almost continously; the others show markets that would peak at about the size of the current U.S. market for VCRs and television sets, which totaled about $11.5 billion in 1987.[7] The AEA forecast for HDTV and associated VCRs is $10.9 billion in the year 2010; the Darby high-growth scenario is $16.2 billion in 2008.[8] The EIA's forecast of $11.7 billion in 2003 for HDTV receivers, but not VCRs, is comparatively high next to the AEA forecast and Darby's high-growth scenario for both receivers and VCRs.[9] By contrast, the Darby low-growth forecast suggests a modest market of less than $600 million in 2008.

Receiver Price

Underlying these forecasts of market value and unit sales are very different assumptions about the pattern of price and cost reductions. Figure 3 shows the price assumptions for each study. Darby assumes that to achieve a high rate of market growth, the prices of HDTV receivers would have to be only a few hundred dollars more than current sets. In the Darby low-growth scenario, HDTV receiver prices remain at about $2,500. By contrast, both AEA and EIA have HDTV enjoying

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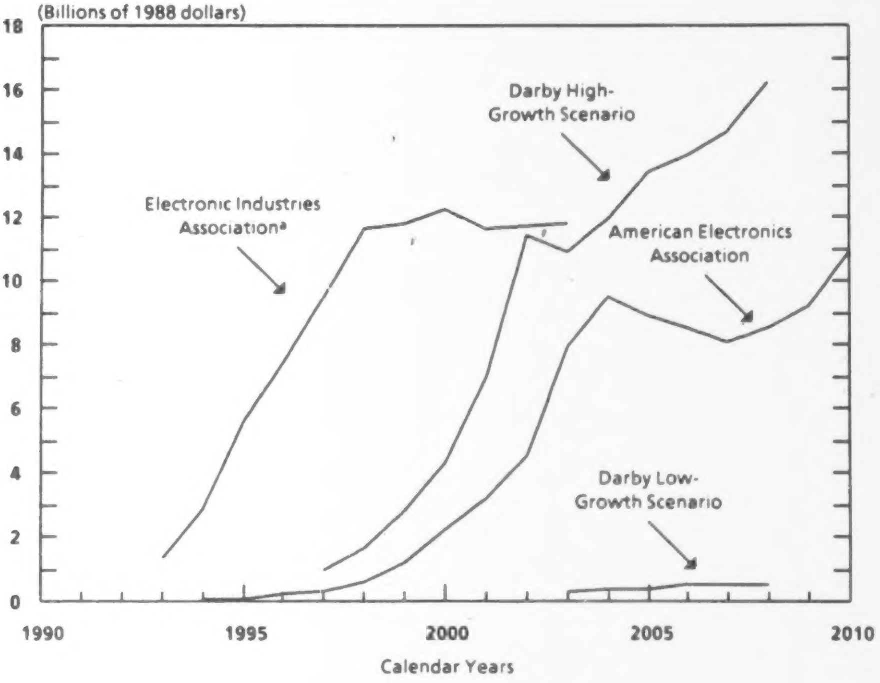
[6] See the Darby report, p. 32. In contrast with the high-growth scenario, the low-growth scenario is undeveloped and had to be reconstructed by CBO. The Darby report states the low-growth scenario is an illustration of a possible range of sales rather than an actual forecast.

[7] Electronic Industries Association, Electronic Market Data Book, 1988 (Washington, D.C: 1988), pp. 18 and 22.

[8] The Darby report has two value trajectories for the high-growth scenario. CBO used the mean of the two.

[9] CBO deflated the EIA value forecasts using EIA's projected average inflation of 3.5 percent per year.

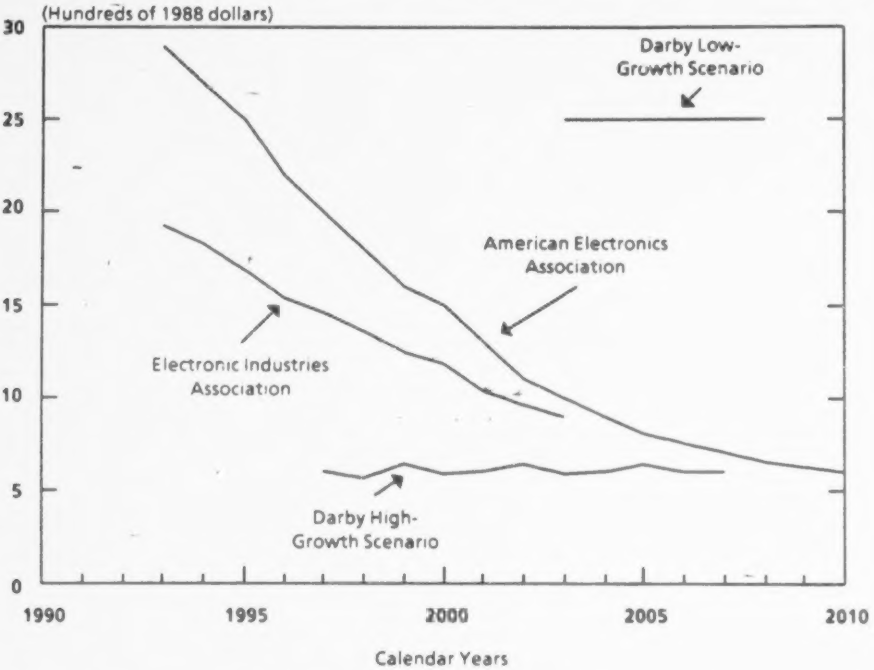
Figure 2.
Projected Annual U.S. Market Value of High-Definition Television Receivers and Related Video Cassette Recorders



SOURCES: Congressional Budget Office based on data from the Electronic Industries Association, "Television Manufacturing in the United States: Economic Contributions--Past, Present, and Future" (produced under contract by Robert R. Nathan Associates, Washington, D.C., February 1989); Department of Commerce, National Telecommunications and Information Administration, "Economic Potential of Advanced Television Products" (prepared for NTIA by Darby Associates, April 7, 1988), referred to as the Darby report; American Electronics Association, "High Definition Television (HDTV): Economic Analysis of Impact" (prepared by the ATV Task Force Economic Impact Team of the AEA, Santa Clara, Calif., November 1988).

a. Excludes VCRs.

Figure 3.
Projected Price of High-Definition Television Receivers



SOURCES: Congressional Budget Office based on data from the Electronic Industries Association, "Television Manufacturing in the United States: Economic Contributions--Past, Present, and Future" (produced under contract by Robert R. Nathan Associates, Washington, D.C., February 1989); Department of Commerce, National Telecommunications and Information Administration, "Economic Potential of Advanced Television Products" (prepared for NTIA by Darby Associates, April 7, 1988), referred to as the Darby report; American Electronics Association, "High Definition Television (HDTV): Economic Analysis of Impact" (prepared by the ATV Task Force Economic Impact Team of the AEA, Santa Clara, Calif., November 1988).

a multimillion unit market with prices well above $1,000, almost triple the current average price of a standard color TV set ($350) and a multiple of the projected value of improved-definition television--an intermediate technology closer to standard color television sets (see Box 1). The EIA and AEA forecasts of market growth would be roughly consistent with the history of color television: in the mid-1960s, the yearly demand for color television sets grew from 700,000 units to 5 million units while color television prices were roughly constant at $1,300 in 1988 dollars.[10] At that time, the differential between monochrome receivers and color receivers was $840 (in 1988 dollars).

EVALUATION OF THE FORECASTS

While a forecast of a new product's sales is subject to a high degree of uncertainty, there is reason to believe that these analyses overstate how rapidly the market will actually grow. CBO makes no attempt, however, to provide an alternative forecast. This section discusses first the assumptions common to all forecasts, and then the methods and assumptions unique to the different studies.

Assumptions Common to All Reports

The forecasts share two critical assumptions--that HDTV will be a success with consumers, and that the market will grow rapidly from the outset. None of the forecasts has a scenario for true failure, even though such products are frequently launched. Many, if not most, new consumer products are not major successes; the video phone and the ultrasound shower, for example, were forecast to be mass consumer products.[11] Many products fail outright, while others take decades to become a major commercial success. Some fail as a result of bad design or marketing, while others fail because of demographic or other factors. In all but the Darby low-growth scenario, however, HDTV receivers are forecast not only to be successes, but to be one of the most successful consumer electronic products of the last several decades. The timing of HDTV's success is also an issue. Considering the differences between HDTV and other successful consumer products--for instance, the VCR is a complement to color television, while the HDTV receiver is a substitute--using their history of success as a pattern for HDTV's market growth may be misleading.

Will Consumers Buy HDTV? The forecasts assume that consumers will prefer HDTV to conventional television. The actual evidence in this regard is mixed, and should temper the forecasts' optimism.

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[10] Calculated from Electronic Industries Association, Electronic Market Data Book: 1988, various pages.

[11] One analysis of new product successes and failures suggests that overly optimistic forecasts for new technology products outnumber accurate ones by between 4 and 7 to 1. See Steven P. Schnaars, Megamistakes: Forecasting and the Myth of Rapid Technological Change (New York: The Free Press, 1989).

A study by the Massachusetts Institute of Technology (MIT), for example, gauged consumer reaction to HDTV in side-by-side comparisons with conventional color television sets. The study found that almost two-thirds of viewers preferred the HDTV sets over conventional sets, but that viewer preference was highly conditional and sensitive to such factors as program content and how close viewers were to the screen.[12] In one instance, 89 percent of viewers watching football footage preferred the conventional color set over the HDTV set when seated about 10 feet (the average home viewing distance) from 18-inch sets (the average size of home television tubes).[13] In another instance, when seated 3 feet (the ideal distance for viewing HDTV) in front of a larger (28-inch) monitor, 95 percent of viewers preferred watching the opening pageantry of the 1984 Olympics on the HDTV receiver rather than on the conventional color receiver. These strong swings in viewer preference in response to screen size, viewing distance, program content, and even color tone serve to reinforce the study's conclusion that "the preference for HDTV...is highly conditional and context dependent."[14]

Since the side-by-side comparison yielded a preference for HDTV, but not a dramatic one, the MIT study questions the claims that HDTV is a technology as revolutionary as color TV was in the 1950s. These doubts undermine the basic assumption that HDTV market growth will resemble the enthusiastic consumer response to color TV. Instead, the MIT study suggests, HDTV may replace mainly large-screen televisions--the so-called premium end of the television market.

The evidence regarding the growth of the premium end of the television market is mixed. On the one hand, analysts such as those at EIA and AEA point to the growing market share of large-screen tabletop television receivers. Television receivers with tubes 19 inches and under represented virtually all sales of tabletop and portable television receivers in 1980, but this share has dropped substantially in recent years and the share of larger-screen television receivers--those with tubes 25 inches and over--has increased quite rapidly. But this growth in market share has come largely at the expense of console television sets, whose share of the market dropped in half during this period. In addition, receivers with larger tubes were not widely available until recently. In fact, the premium end of the television market, defined as the sum of console sales and the sales of tabletop and portable receivers in the largest size category of television tube, has remained constant at roughly one-quarter of all television sales during the 1980s.[15] Finally, the market for very expensive television receivers in the United States is quite small. According to rough estimates provided by EIA's Marketing Services Department, the sales of television receivers with a retail value over $2,000 approach 250,000 units per year, roughly 1 percent of all television sales.

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[12] W. Russell Neuman, "The Mass Audience Looks at HDTV: An Early Experiment" (paper presented at the National Association of Broadcasters' Annual Convention, Las Vegas, Nevada, April 11, 1988). Neuman is an Associate Professor, Audience Research Group, Advanced Television Research Project, The Media Laboratory, Massachusetts Institute of Technology.

[13] According to the MIT Media Laboratory, there were some technical problems with the conventional color tape of the football game, which lowered the amount of detail available but increased the contrast. Since the level of contrast on television is lower than both nature and cinema, the unusual availability of contrast may have influenced viewers' decisions.

[14] Neuman, "The Mass Audience Looks at HDTV," p. 6.

Growth in the premium television market, however, should not be equated with the guaranteed success of HDTV. As noted elsewhere, there are several types of advanced television as well as several premium versions of current television technology. The forecasts offer no reason why one specific technology--HDTV--is the logical successor to the current market leader, even if consumers ultimately accept some form of advanced television. In fact, EIA makes the implausible assumption that sales of any one type of advanced television are unrelated to sales of the other types. HDTV may have more advanced technology than improved-definition television (IDTV) and enhanced-definition television (EDTV), but in the absence of clear signals from consumers, no inferences about its likelihood of success relative to the others are reliable.

The history of television purchases makes it clear that consumers have paid substantial amounts for what they perceived as progress. However, the VCR market has also shown that technical superiority does not necessarily guarantee market success. The major VCR market share, for example, was won not by the company that had the best picture--the BETA format pioneered by Sony was widely regarded as superior--but rather by other factors, such as playing time and price, which favored the VHS format.[16] The issue is whether consumers perceive HDTV as a sufficient refinement over standard color or improved television to warrant the additional expense. Judging from the price differentials forecast by AEA, the price advantages of the older technology may be substantial, especially in the early years when HDTV will cost between $1,500 and $2,300 more than standard color television sets.

How Fast Will HDTV Develop? Another assumption common to all forecasts is that HDTV manufacturers are going to "get it right"--that is, produce the exact product consumers want--the first time. This assumption is questionable. In the case of the video recorder, 10 years of unsuccessful consumer-oriented video recorders preceded the introduction of the model that became an "overnight success."[17] The features that have made today's VCRs so popular were not apparent or even possible in the period when firms first decided to develop a consumer video recorder. Indeed, consumers have probably been doing some learning also, discovering what they really desire. For example, the ubiquitous personal audio cassette player is an obvious case of consumers not realizing they had a need until they actually saw the product. Similarly, the microwave oven languished for 20 years after its introduction until costs finally declined and families with two working parents found that they needed a way of preparing food rapidly.[18]

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[15] Data supplied by EIA Marketing Services Department. The categories of the tube sizes shifted each year. In 1980, the largest category was 20 inches and over, while in 1988 the largest category was 28 inches and over.

[16] James Lardner, Fast Forward: Hollywood, the Japanese, and the VCR Wars (New York: New American Library, 1988), pp. 151-162.

[17] Richard S. Rosenbloom and Michael A. Cusumano, "Technological Pioneering and Competitive Advantage: The Birth of the VCR Industry," California Management Review (Summer 1987), pp. 51-76.

One issue that is particularly relevant to the timing of consumer purchases of HDTV is the availability of programming specifically for HDTV receivers. Color television sales, for example, did not really increase until color broadcasting became widespread. The investment decisions made by producers of television programs and other "software" that may be available for HDTV will be critical to consumers' desire to purchase the new sets, and vice versa. Any delay in programming availability, or a perception by consumers that HDTV programming is not substantially different from current programming, would probably also delay consumer interest in switching to HDTV.

The implication of these product histories and associated investment decisions about programming is that the commercial acceptance of HDTV may be a long time coming. There is no reason to assume that HDTV manufacturers will "get it right" the first time or that producers of television shows will decide to make their current production equipment obsolete by quickly shifting to HDTV production. Even if advanced television ultimately replaces the current color television system, that path may be more tortuous and may take much longer than the optimistic forecasts suggest. And, the final product may look very different from that envisioned by today's engineers.

Assumptions Specific to the Individual Reports

In addition to the common assumptions detailed above, each report makes specific statements or assumptions that deserve particular attention. These assumptions are examined below.

Darby Report. The Darby high-growth forecast assumes that HDTV receivers will be priced at roughly $600 during the early years of market penetration. But this assumption of such a low and constant price is neither realistic nor necessary for the growth of the HDTV market. As noted above, sales of color television receivers in the mid-1960s grew almost tenfold while the price was well above $1,000 in 1988 dollars. Furthermore, the forecast is not consistent with the type of price decline expected with the introduction of new consumer electronics. Unless the costs of electronic components decline at a much faster rate than is typical of new products, companies selling HDTV receivers priced at $600 may be selling them at a loss.

Electronic Industries Association. One potential problem with EIA's forecast of HDTV sales is that its underlying forecast of total television demand is questionable. It forecasts that the total demand for color television receivers in the year 2003 will be 40.2 million units, double the current level of 20.3 million units. CBO's initial statistical checks suggested, however, that this estimate may be high relative to demographic and economic variables forecast for the next two decades. While the 1988 sales level is in turn double the 1978 level, demand in the 1980s has been driven in part by such demographic factors as the economic maturation of the baby-boom generation. These demographic factors will not be as favorable over the next decade and a half. The U.S. television industry has also enjoyed a continuous consumer-led expansion since 1983. If overall economic growth in the future is less robust or is not led by purchases of consumer goods, the demand for television of all kinds may be depressed. On the other hand, the development of a large market for portable or small-screen televisions may increase television sales substantially.

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[18] Schnaars, Megamistakes: Forecasting and the Myth of Rapid Technological Change, p. 110.

American Electronics Association. The AEA forecast presents EDTV as becoming a very successful product, reaching annual sales of 1 million units within 3 years of introduction and 14 million units within 15 years; HDTV reaches a similar level within a similar time frame. It is questionable, however, that two advanced television technologies will be so successful within such a short time. Competing technological starts within the same medium can coexist (for example, Apple and IBM personal computers), but it is just as likely that one will edge out the other as occurred between BETA and VHS formats of VCRs, or, more broadly, between videotape and videodisc technology. Black and white and color TV sets were very successful in overlapping periods during the late 1950s and early 1960s, but after color sales exceeded 1 million units per year, monochrome television began a long decline.

The issues regarding the coexistence of various forms of advanced television are also related both to the number of ancillary investment decisions that have to be made and to the cost of serving the two markets. In BETA and VHS, the video rental stores (and consumers) wanted one standard in order to minimize their investment in any one movie, and their decisions probably helped speed the demise of BETA. Depending on the specific nature of the incompatibilities of EDTV and HDTV, most notably in their VCRs, the two technologies may or may not be able to coexist.[19]

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[19] This analysis assumes that VCRs for all types of advanced television will be upwardly compatible--that is, an IDTV tape could be played on an HDTV set but not the reverse. This is currently the case with VHS and super VHS. Furthermore, there are no advantages to playing an IDTV tape on an HDTV VCR because the tape will not contain sufficient information for the receiver to create an HDTV image.

CHAPTER III

ECONOMIC EFFECTS OF HDTV ON RELATED INDUSTRIES

To many industry analysts, concern about the HDTV market is but one facet of a more general concern about the U.S. semiconductor industry and other U.S. electronics industries. These concerns are evidenced primarily by the broad range of effects that HDTV is claimed to have on other segments of the overall electronics sector, and by the degree to which the relatively small HDTV market (even under the most optimistic market forecast) is supposed to influence activities in much larger markets. In reviewing the claims for HDTV made in the market forecasts, CBO found, in general, that either the markets were unlikely to be big enough to have the desired effects, or the sequences of events asserted by the studies were not sufficiently developed to warrant the conclusions that were drawn.

The following sections analyze the specific claims of the three market forecasts for the effect HDTV might have on related products, particularly on products such as semiconductors that would become inputs into HDTVs. Supporters generally argue that HDTV sales could create an enormous demand for U.S.-manufactured inputs, and that U.S.-based firms would become more competitive as a result of supplying products to HDTV manufacturers. In most cases, CBO found that the ability of potential suppliers of semiconductors, flat-panel displays, and computers to compete in international markets would probably not be determined by the success or failure of the HDTV market. Rather, changes in U.S. market share in most of the supplier markets are more likely to result from the actions of firms and the development of technologies within those markets than from pressures or advantages created by HDTV.

CONCLUSIONS OF THE MARKET STUDIES

The market forecasts of the three studies are used to address two different, but related, economic questions:

- How would HDTV affect U.S. employment and output? and
- How would HDTV affect the competitiveness of the U.S. electronics sector?

The AEA report seeks to show how the presence of U.S.-based firms in a successful HDTV market would affect their ability to compete in the markets of other electronic goods. The EIA report attempts to determine how the U.S. economy--value added and employment, in particular--would be affected by a change in the combination of products that would result from a large HDTV market. The Darby report provides only illustrative statistics of HDTV's effect on domestic output and employment and does not make specific predictions about the effects of HDTV on the competitiveness of the U.S. electronics sector. Moreover, Darby does not examine the consequences of the low-growth scenario, in which HDTV becomes a niche product.

Competitiveness of U.S. Electronics Firms

In the AEA report, the HDTV market is valued not only for its contribution to overall employment and income but because, AEA argues, it is big enough to help U.S. electronics firms advance their technology and become competitive in other areas, and it involves the development of particular technologies that will serve as "technology drivers" for the rest of the sector. Implicit in the AEA analysis is some combination of economies of scale and learning curves that results in cost reductions as sales rise (even in related markets), and a network of common technologies and components that makes the knowledge gained in HDTV markets applicable throughout the electronics sector.

The AEA report assumes that the U.S. market shares in semiconductors, personal computers, and other electronics industries are directly related to the U.S. market share in the HDTV industry: the lower the U.S. share in the HDTV market, the lower will be its market share in these other industries.[20] It also assumes that if the U.S. participation in HDTV is just slightly smaller than the U.S. participation in conventional television is now--roughly 13 percent of the world market--U.S. semiconductor manufacturing firms could lose up to 50 percent of their world market share. Even if the U.S. market position in HDTV is more than double the current U.S. market position in conventional television, AEA assumes that U.S. semiconductor firms would lose 20 percent of their world market share. Only if U.S. firms capture at least 50 percent of the U.S. HDTV market can U.S. semiconductor firms be assured of retaining their current share of the world semiconductor market. The AEA forecast assumes similar, though sometimes smaller, declines in world market shares of U.S.-based producers of personal computers and automated manufacturing equipment, depending on the positions of U.S.-based firms in the U.S. HDTV market.

Contributions to U.S. Output and Employment

The EIA analysis argues that regardless of whether the firms that make the HDTV receivers are foreign- or domestic-based, the bulk of the economic effect--on employment and value added--will occur in the United States. Forecasting from current trends, the report states that over 90 percent of the HDTV receivers destined for the U.S. market will be produced in the United States and that roughly 85 percent of the value of those units will be of U.S. origin.[21] This domestic production would increase U.S. value added by $6.2 billion, relative to what it would have been if HDTV technology was not commercialized. This increase in U.S. output would raise employment by 130,000 in HDTV manufacturing, and would create an additional 103,000 jobs through secondary effects.[22] The Darby high-growth scenario presents a similar increase of 240,000 jobs.[23]

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[20] The ATV Task Force of the AEA made these assumptions about declining market share of U.S. firms based on the opinions of their panel of executives and engineers from the electronics industry.

The EIA's rationale for the large effect on U.S. value added is based on the fact that almost all television sets with screens larger than 20 inches are manufactured in the United States, albeit predominantly by foreign-based firms.[24] Since the benefits of HDTV are best realized in larger sets, the U.S. HDTV market is likely to be dominated by larger sets and hence largely served by local manufacturing plants, regardless of ownership. Because they are fragile and bulky, large glass tubes are expensive to ship. Consequently, television manufacturers are increasingly locating their glass tube plants in the United States, even though the electronic components within the tubes are often imported. Furthermore, a more recent EIA-sponsored study found that, in 1987, the average domestic content of a color television receiver produced in the United States was 70 percent, and the share was over 80 percent for larger sets.[25]

HDTV AND THE COMPETITIVENESS OF THE ELECTRONICS SECTOR

As noted, the three reports discussed here use their forecasts of HDTV sales to generate additional predictions. They discuss the effect of HDTV on the output and employment of the U.S. economy. They also consider the effects of HDTV on the technology, competitiveness, and market shares of U.S.-based firms that manufacture electronic components and equipment.

The forecasts of output and employment in the electronics sector are derived from input-output analysis and industry rules of thumb, which have both advantages and limitations. Economists differ regarding the usefulness of these methods to forecast changes in output and employment. They agree that in an economy at full employment--where most analysts feel the U.S. economy to be in 1989--gains in one sector can come only at the expense of losses in others. But they disagree both on the potential for overall economic gains if the economy is at less than full employment, and on the possible contributions to the economy that might occur from an accelerated shift of resources away from more stagnant sectors and toward more dynamic sectors. Rather than focus on speculative effects that are probably not unique to HDTV, this section examines the more tangible effects that HDTV manufacturing might have on the competitiveness of U.S.-based firms.

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[21] The 85 percent domestic content assumes that 100 percent of the electronic components, other than the tube, are imported. All tubes are assumed to be of U.S. origin. Should U.S. electronic components such as proprietary microprocessors be incorporated, the U.S. content would rise. Conversely, foreign subassembly might reduce the U.S. content. See the EIA report, "Television Manufacturing in the United States: Economic Contributions--Past, Present, and Future," pp. 50 and 68.

[22] EIA report, pp. 73-76.

[23] Darby report, "Economic Potential of Advanced Television Products," p. 43.

[24] EIA report, p. 1.

[25] Electronic Industries Association, Consumer Electronics, HDTV and the Competitiveness of the U.S. Economy (Washington, D.C.: February 1, 1989), p. 37.

According to the rationale behind the AEA forecast, the technology developed to serve the HDTV receiver market will allow foreign firms that have this technology to use it to become dominant in other electronics markets, from personal computers to communications equipment to workstations. The advantages of the high-resolution displays and serving the massive home market for HDTV receivers overwhelms whatever technical advantages U.S.-based firms might have within these product categories. The loss of the electronic goods markets might also subsequently entail a loss of the markets for the components used in those goods, especially semiconductors.

This possible sequence of events is not only forecast by the AEA, but is widely believed within the electronics industry. In its report, however, the AEA does not show how advantages in one area (display or imaging technologies, for example) confer such overwhelming advantages to all other markets for electronic goods. In the one market it does discuss--personal computers--this foreign advantage in display technology results in a 50 percent decline in the world market share of U.S.-based producers. Thus, the technical advantage would have to be great, though AEA offers no evidence that such an advantage would occur. (The personal computer industry is discussed in more detail below.)

A market as small as that forecast for HDTV is not likely to affect substantially the U.S. market share in computers, communications equipment, and other electronic equipment. These markets are already large and continue to grow rapidly, and they will probably remain far more significant factors than HDTV in the evolution of electronics technology. While the AEA report forecasts a $28.5 billion world market for HDTV receivers and VCRs by 2010, other U.S. electronics industries are already much larger and are likely to continue to grow at a significant pace over the next two decades.[26] Taken together, the world electronic equipment sector grew by $54 billion in 1988 to reach $461 billion.[27] Thus, not only is this sector more than 15 times larger than the HDTV market, but also its annual growth is almost double that projected for the HDTV market.

While the effects of HDTV on the commercial development of the electronics sector may be quite limited, some analysts feel that consumer electronics as a whole

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[26] AEA report, "High Definition Television (HDTV): Economic Analysis of Impact," pp. 2-4 and 2-6.

[27] "1989 U.S. and Overseas Market Forecast: Looking for a Soft Landing After Hypergrowth," Electronics (January 1989), p. 54.

(of which HDTV would be a part) plays an important role in the creation and maintenance of a competitive electronics sector.[28] First, the consumer electronics market is sizable in its own right: about 3 out of every 10 integrated circuits manufactured worldwide go into consumer products, although, in the United States, the share of consumer electronics is only 15 percent.[29]

Second, there is a perception that Japanese electronics companies have used the consumer market to build up their capabilities and expertise in manufacturing semiconductors and other electronic goods. Although the technology used in consumer products is not as sophisticated as that used in other electronics markets, keeping cost down is much more important and, some argue, this ability to control costs carries over to other areas. In this regard, Japanese domination of the market for liquid crystal displays and charge-coupled devices--the light-sensitive integrated circuits that make camcorders work--is seen as having come from their strong position in the VCR, wristwatch, and other consumer markets. Similarly, surface-mounting technology, a lower-cost method of mounting components on printed circuit boards, first enjoyed widespread use in consumer electronics before being introduced into computers and other areas. On the other hand, the single largest market success of Japanese semiconductor companies--the computer memory market --has thus far had little to do with the consumer market: Japanese companies had to develop that expertise directly, by manufacturing memory devices for overseas markets. In addition, cost control is not as important in other markets: performance or some other factor is often of much greater importance than a small reduction in purchase price.

Policy discussions concerning the influence HDTV might have on the production of other electronic goods often center on semiconductors, personal computers, and flat-panel displays. These products are discussed below.

Semiconductors

The AEA forecast assumes that if U.S.-based firms fail to control a substantial portion of the HDTV market, U.S.-based semiconductor makers will be frozen out as suppliers to this market by the foreign HDTV producers. It also assumes that foreign producers of semiconductors selling into the HDTV market will gain vast experience and be able to reduce their costs, thus driving U.S. semiconductor makers out of even more markets. This scenario seems implausible in three main areas: the size of the demand for HDTV semiconductors, the ability of foreign semiconductor producers to transfer gains in one market into gains elsewhere, and the assumed behavior of U.S. HDTV makers.

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[28] See Electronic Industries Association, Consumer Electronics, HDTV and the Competitiveness of the U.S. Economy.

[29] Congressional Budget Office, The Benefits and Risks of Federal Funding for Sematech (September 1987), p. 19.

Demand for HDTV Semiconductors. The AEA estimates that the use of semiconductors in HDTV receivers worldwide will total $1.8 billion in 2010.[30] The same report projects a worldwide semiconductor market of $303 billion in 2010 (see Figure 4). Even after demand for HDTV has started to grow, semiconductors used in HDTV receivers will still represent less than 1 percent of AEA's forecast of total demand for semiconductors.

The AEA then argues that the difference between U.S. firms controlling 10 percent of U.S. HDTV sales and 50 percent of U.S. HDTV sales is the difference between realizing economies of scale or learning effects in the manufacture of semiconductors and not realizing these gains. Even assuming that U.S. firms buy only U.S. integrated circuits and foreign firms buy only foreign integrated circuits --an extreme assumption--the maximum difference between these two scenarios is $272 million. Thus, the AEA report assumes that the $272 million difference reduces U.S. production costs sufficiently to increase total U.S. semiconductor sales from $62 billion (20 percent of the world market) to $124 billion (40 percent of the world market). This assumption seems implausible. Even if the worldwide HDTV market is included, the learning effects or scale economies to be realized by additional sales of $735 million, or 0.2 percent, of semiconductors worldwide, are extremely unlikely to be that large.[31]

The AEA figures also suggest that television receivers sold in the United States, including HDTV, will use a declining share of semiconductors over the forecast period: in 1990, receivers sold in the United States will consume 1.4 percent of world semiconductor production, falling to just 0.4 percent in 2010. Even under AEA's forecast for worldwide HDTV sales, the HDTV market would account for less than 1 percent of semiconductor sales, assuming that foreign HDTV receivers have the same semiconductor content as U.S. HDTV receivers. And, in absolute terms, AEA's projections do not show that U.S. HDTV production will require significantly more semiconductors by 2010 than conventional color television will use in 1990: $682 million versus $664 million, respectively.

The AEA and others argue that, although the absolute size of the HDTV semiconductor market might be small, the integrated circuits required are so sophisticated that HDTV technology will drive engineering innovation. This seems

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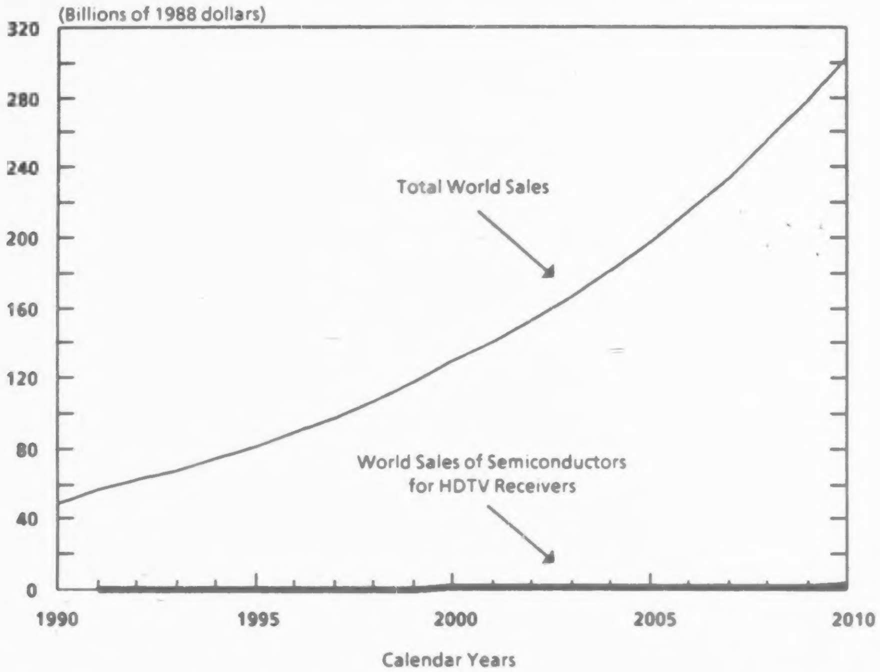
[30] Calculated from the AEA report, pp. 2-3 and 2-10. Because AEA has no estimate for the use of semiconductors in the HDTV VCRs, this estimate understates the complete value of semiconductors used in HDTV. This and other forecasts suggest that between 6 percent and 12 percent of HDTV retail value is attributable to semiconductor costs. For data on the semiconductor content of HDTV, see the AEA report, pp. 2-4 and 2-10; and the EIA report, p. 50.

[31] The figure of $735 million is derived by dividing $272 million (the assumed loss within the U.S. market) by 37 percent (the U.S. share of the world HDTV market). This calculation assumes that all HDTV receivers worldwide have the same semiconductor content and that U.S.-based firms are going from a 10 percent to a 50 percent share of the worldwide HDTV market.

Figure 4.
AEA Forecast of World Sales of Semiconductors



SOURCE: Congressional Budget Office using data from American Electronics Association, "High Definition Television (HDTV): Economic Analysis of Impact" (prepared by the ATV Task Force Economic Impact Team of the AEA, Santa Clara, Calif., November 1988).

NOTES: Assumes that semiconductor content of non-U.S. HDTV receivers is the same as that of U.S. receivers. Excludes HDTV video cassette recorders.

highly unlikely for the following reasons. First, the U.S. semiconductor industry spends over $2 billion each year in R&D, and federal agencies spend another $500 million, independent of HDTV.[32] The level of HDTV R&D specifically devoted to integrated circuit R&D is likely to be much lower than this. Assuming that all R&D is equally productive, most semiconductor engineering innovations are more likely to come from the semiconductor R&D already in place than from marginal HDTV R&D programs. Second, neither the memory devices nor the digital signal processors--the most common types of integrated circuit used in HDTV--are more sophisticated than those currently produced by the semiconductor industry. U.S. makers of integrated circuits already produce microprocessors with 1.2 million transistors each.[33] Finally, U.S. semiconductor manufacturers have traditionally led in design innovation while exhibiting weakness in manufacturing ability. This lead in design innovation is long-standing and cuts across many product categories. It seems unlikely that one program could reverse this long-standing advantage.

Although it is unlikely that HDTV receivers will drive semiconductor technology in the aggregate, they may do so for specific integrated circuit submarkets. Digital television receivers are voracious consumers of digital signal processors. Estimates suggest that this market is currently in the $500 million range, of which U.S.-based firms produce $300 million.[34] While the consumer portion of that market is only 5 percent to 6 percent of the total, it is growing. Thus far, however, firms with expertise in producing digital signal processors for consumer markets have not had much success in penetrating other portions of the digital signal processor market. To be made cheaply, consumer digital signal processors have to be simple and dedicated. Hence, they have very little software and little peripheral support. Whether HDTV would represent a sufficiently large market to overcome this limitation is not clear.

Transferring Market Gains. The AEA data on market share also assume that all semiconductors are the same and that improvements in the manufacturing process are immediately transferred from one type of device to the other. In fact, integrated circuits serve many different purposes, and advances in one market do not immediately transfer to another. For example, Intel Corporation makes the microprocessors for IBM-compatible personal computers. Intel owns the property rights to those designs, and advances in memory technology alone will not permit another firm to produce those integrated circuits. If anything, the trend in personal computers (and other electronic devices) is to increase the use of integrated circuits with proprietary designs while decreasing the share of devices whose design is nonproprietary. The increasing use of application-specific integrated circuits is one concrete example of this trend. If this trend continues, then the markets are likely to become increasingly compartmentalized because of particular design expertise, making the wholesale decline in U.S. semiconductor industry even less likely. But this compartmentalization also means that the mass market effects would be less likely to revitalize the industry. The various semiconductor markets are not completely isolated from each other. Rather, each market has its own internal logic and dynamism, and gains in one market translate into gains in other markets only as this logic and dynamism allow.

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[32] Congressional Budget Office, The Benefits and Risks of Federal Funding for Sematech, p. 43.

[33] Jonah McLeod, "They're Faster, They're Denser, and They're Here: 80486 and 68040 Debut," Electronics (April 1989), pp. 27-28.

[34] Jonah McLeod, "32-Bit Floating Point: The Birth Pangs of a New Generation," Electronics (April 1989), p. 72.

Behavior of U.S. and Foreign HDTV Producers. There is little reason to believe that HDTV components, other than the picture tube and cabinetry, will necessarily be manufactured in the United States. During the 1980s, U.S. personal computer companies experienced the type of growth that HDTV advocates hope for. Yet during that time, all but three U.S. semiconductor manufacturers stopped making dynamic random access memories (DRAMs)--a principal component for the personal computer. Furthermore, U.S. manufacturers of personal computers seemed as willing to buy Japanese and Korean DRAMs as U.S. integrated circuits. One would assume that U.S. HDTV manufacturing firms would also buy foreign integrated circuits. If HDTV causes a substantial expansion in demand for DRAMs, this additional demand is most likely to go to firms that already manufacture them.

The assumption that U.S.-based semiconductor producers will be excluded from the HDTV market if U.S.-based firms are not manufacturing receivers also ignores the recent performance of U.S. semiconductor companies. One of the leading firms in producing advanced digital integrated circuits for conventional color receivers is a U.S. firm, ITT Semiconductors. In fact, it enjoys a substantial market share in Europe, where there are no U.S. producers of television receivers. This firm has already announced its intention of producing integrated circuits for HDTV receivers, regardless of where those receivers are made.

Given the experience in the DRAM markets in the mid-1980s, however, U.S. semiconductor manufacturing firms and federal agencies responsible for trade are unlikely to allow U.S. component makers to be removed from the component businesses in which they now have substantial presence. Even though most of the problems for U.S. makers of integrated circuits during the 1984-1986 semiconductor slowdown were the result of declines in demand for semiconductors rather than the result of an increase in foreign market share, U.S. policy is currently much more sensitive to potential technology losses.[35] Furthermore, some U.S.-based semiconductor producers and users have started to form a consortium to produce DRAMs in the United States. This move indicates a greater awareness on the part of semiconductor consumers regarding the desirability of having domestic sources of semiconductors.

Flat-Panel Displays

The other component technology frequently mentioned in connection with HDTV is the flat-panel display. The three forecasts generally assumed that cathode ray tubes would be used for most HDTV receivers; flat-screen displays are currently

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[35] Congressional Budget Office, The Benefits and Risks of Federal Funding for Sematech, pp. 15-16.

much smaller and much more expensive than tubes.[36] But HDTV engineers want ultimately to make the receiver displays using flat screens, which would then permit consumers to fit large receivers into their homes. Since the visual difference between HDTV and conventional color television is more noticeable with larger screens, HDTV advocates argue that flat-screen television will create both the demand and the opportunity for the HDTV market to grow. In addition, since the large-screen segment of the television market is growing, linking HDTV to a large-screen technology should improve its chances of success. The Japanese government, in conjunction with several large electronics firms, has begun a $75 million joint research effort to develop large flat-panel displays for possible use in HDTV. This highly publicized, multiyear effort has further spurred concern that U.S.-based firms will find themselves at a technological disadvantage in this market unless they initiate a similarly large research effort.

While the development of flat television receivers has been long awaited, they are just now becoming feasible. Even so, despite the Japanese research effort and new DARPA funding, success is not guaranteed, as major technological and economic hurdles must be overcome. For instance, with liquid crystal displays--the kind most commonly used for flat panels--the display panel is essentially a large integrated circuit: a 12-inch screen is a 12-inch circuit. In addition, manufacturing a liquid crystal HDTV screen is the equivalent of making an integrated circuit that has 1.6 million transistors, which is as many components as the most sophisticated integrated circuits currently have. The fabrication of such massive integrated circuits at reasonable cost will be a technological challenge.[37]

If flat-screen color television becomes a reality, it will be a major step forward in consumer electronics and could affect other parts of the electronics sector. Last year, nearly 750,000 laptop computers were sold in the United States, most at premium prices. Most of these had some form of flat screen. The screens for color television need to be better in several ways than the screens for personal computers. Television receivers need full-motion video, while, outside of engineering workstations, computer monitors do not need this level of quality. Consequently, any firm that masters the technology sufficiently to produce flat-color television receivers will be well positioned in the market for flat-panel computer monitors.

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36. Only the AEA assumed that flat screens would account for a sizable segment of the market, and they assumed it would be at the premium end of the HDTV market. Their forecast assumes that sometime in the next 5 to 10 years, relatively small expensive panels of HDTV quality will appear, but that these panels will become large and less expensive over the succeeding period.

37. Rather than being a fraction of an inch square, a flat-panel display would be much larger, increasing the opportunities for flaws in the materials and errors in manufacturing. Since part of the success in making integrated circuits more dense and more cheaply has come from reducing their size, conventional processing techniques will be unusable. See Samuel Weber, "It's a New Age for LDCs," Electronics (May 1989), pp. 96-100.

But, if quality flat-panel displays can be made at reasonable costs, they will come into widespread use whether HDTV becomes a reality or not. They could be used as substitutes for television tubes of any format: conventional color television or any of the three advanced television formats. In fact, small conventional television receivers that use flat-panel displays are now available commercially. If flat-panel displays of the right size and cost become available, they may appear first in non-HDTV formats, particularly if HDTV technology is delayed. In addition, the use of flat-panel displays in computers is growing independently of developments in HDTV. On the other hand, if HDTV and flat-panel television succeed as a joint product, then the EIA forecast of domestic content, which is predicated on U.S. production of large picture tubes, may prove incorrect because flat panels may be easier to import than the more fragile picture tubes.

The United States, however, already imports many, if not most, of its computer monitors. According to the Department of Commerce, 8.9 million monitors, worth a total of $1.9 billion, were imported in 1988. South Korea and Taiwan together provided almost half of the total. Thus, even if flat-panel displays become much more widely accepted for use in computers, they may largely substitute for terminals the United States currently imports. In addition, the presence of so many low-cost substitutes means that Japanese producers of flat-panel displays may be unable to charge very high prices for their devices outside of specialized markets, such as the laptop computer. On the other hand, many in the U.S. industry worry about the long-term implications of relying too heavily on Japanese competitors for an input as crucial as the display, especially if it eventually supplants the cathode ray tube.

Personal Computers

The AEA report assumes that HDTV technology will be the difference between the U.S. personal computer industry holding its current world market share (70 percent) or declining to half that level. They argue that without the incentive of HDTV technology, U.S. personal computer technology will fall behind and foreign competitors will thereby increase their market share.[38]

How realistic is this scenario? Foreign competitors may or may not increase their share of the U.S. personal computer market, but U.S. firms already have every incentive to perform R&D and improve their manufacturing processes. The U.S. personal computer market was $23 billion in 1988, according to industry figures.[39]

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[38] AEA further assumes that the U.S. market share in personal computers could be cut in half by 1990--a date when its forecast suggests a total U.S. HDTV market of only 1,000 sets--unless the federal government and U.S. manufacturing firms aggressively pursue HDTV.

[39] International Data Corporation, cited in Karen Blumenthal and Robert Tomsho, "An IBM Tagalong Sets Independent Course, with Plenty of Risks," Wall Street Journal, April 21, 1989, p. A1.

The U.S. IBM-compatible market alone was roughly 7 million machines in 1988.[40] By contrast, according to AEA's estimates, the U.S. HDTV market is not expected to reach that level until after 2007. Furthermore, AEA's sales projection assumes that HDTV prices will be well below $1,000 per machine, whereas the average price of the IBM-compatible personal computer is well above that. Thus, the assumption that U.S. personal computer technology will be driven by HDTV technology requires that U.S. personal computer manufacturing firms place more emphasis on a small market that may or may not exist in 2007, and less emphasis on a $23 billion market that exists today. Common sense and economic theory indicate the opposite.

Research and development for HDTV might be producing new designs and advances, but the U.S. computer industry is not standing still. According to the National Science Foundation, U.S. computer makers spent $8.5 billion of their own funds on R&D in 1987 alone. While not all or even most of this money was for personal computers, it indicates the level of funds available to advance related technology. Thus, unless HDTV R&D is especially productive, the major advances in computer technology will most likely come from within the industry.

Although HDTV receivers can be viewed as dedicated computers, they will not be able to run conventional software unless they are substantially modified. Most people buy personal computers because of the software. The hardware may make the software run faster or better, but the software--word processing, spreadsheets, desktop publishing--is ultimately what determines the use of the computer. Given the existing base of software--$15 billion for the IBM-compatible personal computers alone--one would assume that most computer users would not leave their existing computers just because better displays were available on HDTV receivers. If, on the other hand, HDTV receivers incorporated personal computers that are compatible with existing software, their complexity (and cost) would be much higher, and they would be at a competitive disadvantage in both the receiver and the personal computer markets.

When focusing on the computer market, analysts sometimes forget that the market for computer peripherals, such as printers, is also large and that the devices are complex. Many of these peripherals are almost as complex as the HDTV is forecast to be, and their markets are as large as the near-term forecast for HDTV. Some of the devices now thought of as printers are, in fact, small computers. For example, the popular laser printer has a microprocessor and almost as much memory (and more can be added) as most personal computers. As semiconductor costs decline, other computer peripherals might increase in popularity. The optical scanner, for example, is waiting for cost reductions to move into the mass market. With the right software and enough memory, the scanner may be able to read magazine articles and other printed matter directly into a computer and store it in machine-readable form for later use.[41] The current optical scanner market for computers is over $800 million per year, a figure that AEA's combined market for HDTV receivers and VCRs is not forecast to reach for another decade.[42]

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[40] Michael Alexander, "Users Calm About Clone Battle," ComputerWorld, March 27, 1989, p. 43.

[41] Roberta Furger, "A Technology Comes of Age," Infoworld, June 12, 1989, pp. 47-51. One type of scanner--an optical character reader--needs an average of 4 megabytes of memory, exactly the size projected for an HDTV receiver.

One technology thrust in computers, which runs parallel to but is independent from HDTV, is the development of higher-resolution displays. Computer-aided design and engineering often need high-density displays.[43] Makers of IBM-compatible computers already offer graphics systems with the same number of lines currently planned for HDTV.[44] Throughout the electronics sector, increased use of digital imaging systems as parts of larger electronic systems is widely discussed. It is quite likely, therefore, that a portion of the computer market will soon be using display systems that resemble HDTV displays. Because of this similarity, there might be some transfer of technology between the high-resolution display and HDTV. But the dynamics of that market are quite different from those of the consumer market on which these three reports focus. For one thing, these uses will largely be determined by software: unless the design software is available, the users are not likely to demand a specific hardware system. In addition, these premium displays are usually purchased as part of an equipment system and so are only one factor in the decision to purchase the whole system. In any event, these uses will initially be of interest to a limited segment of the market.

CONCLUSIONS

This report has examined three forecasts of the potential HDTV market and analyzed them to answer two questions: (1) Will there be a large market for HDTV receivers? and (2) Is this market critical to the competitiveness of the U.S. electronics sector? The forecasts are very optimistic with regard to market size and certainly with regard to timing, although some consumer electronics products have enjoyed the level of success they project.

Evaluation of forecasts of HDTV's effect on other electronics markets seems clearer. Even the optimistic forecasts of the HDTV market are small relative to the other electronics markets. Thus, it is unlikely that HDTV will by itself revitalize the U.S. electronics sector.

These conclusions do not necessarily mean that federal support for HDTV development is without merit. Some might support HDTV for reasons other than competitiveness in the electronics sector--for instance, employment, national prestige or scientific advancement. The Department of Defense has a long history of pursuing display technologies that have possible military uses. In addition, HDTV development, although small on its own, might have a role to play in a broader strategy for the U.S. electronics sector.

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[42] "The PC Juggernaut Bogs Down," Electronics (January 1989), p. 59.

[43] Tom Manuel, "PC Graphics," Electronics (April 1989), pp. 84-88.

[44] Bob Ponting, "Beyond VGA," Infoworld, June 26, 1989, pp. 45-49.

TESTIMONY OF

JUAN A. BENITEZ

DEPUTY ASSISTANT SECRETARY

FOR SCIENCE AND ELECTRONICS

Before the

GOVERNMENTAL AFFAIRS COMMITTEE

UNITED STATES SENATE

on

HIGH DEFINITION TELEVISION

TUESDAY, AUGUST 1, 1989

Mr. Chairman and members of the Committee, I am very honored to have the opportunity to discuss the scope of HDTV and the implications the development of HDTV and related technologies has for the competitive and economic position of the United States.

Mr. Chairman, having spent all of my professional life in the private sector, as both an engineer and a businessman, with the last 11 years in the semiconductor industry, I find it very challenging and stimulating to have been asked to analyze the economic opportunities presented by HDTV. I can also appreciate the operating importance of creating new markets to maintain pace with growth, especially in the electronics industry where product life is short, development times are becoming longer, and continuous capital needs are paramount.

It is important to qualify what HDTV represents. HDTV is more than a single new consumer electronics breakthrough. It is not even a single technology. Rather, it is an important new application, or set of applications, of several evolving technologies and markets, such as: semiconductor memory, digital processors, flat panel displays, fiber optics, and integrated services digital networks. Advances in these technologies and markets for HDTV would, in turn, apply to advanced computers, industrial imaging, medical diagnostics, robotics, factory automation, defense displays, and information systems and networks. In other words, advanced television should be viewed as a natural progression of computers and advanced information systems.

By stressing that HDTV is more than a single technology, I do not mean to minimize the significance of HDTV as a breakthrough in home entertainment. Nor should we minimize the importance of this consumer electronics market. However, we should emphasize that HDTV will provide the linkage to several interrelated end-user markets.

Since HDTV is highly semiconductor-intensive, it carries special promise for the U.S. semiconductor industry. Advanced TV applications make heavy use of memory chips, digital signal processors, converters, and other microprocessors. For example, it is estimated that an HDTV set will use up to 50 megabytes of memory, which is 50 times the capacity used in one of today's personal computers. This market could provide the "critical mass" of demand needed to invigorate the U.S. semiconductor industry and to achieve important economies of scale. This, in turn, could allow the industry to generate the large and continuous capital needs that are inherent of the semiconductor industry.

In view of the overwhelming importance of electronics and computers to industry and the military, as well as to consumers, significant U.S. participation in HDTV can enhance the economic linkage between the U.S. electronics industry and the U.S. competitive position overall.

Mr. Chairman, I would like to discuss some of the Administration's initiatives that can help foster U.S. participation in developing HDTV and products using other emerging technologies. President Bush has recommended to Congress that the capital gains tax be reduced and that the Research and Experimentation Tax Credit be improved and made permanent. These measures will provide added incentives for the long-term commitment of resources to technology development and improvements in manufacturing.

The Administration is also considering options to clarify the effect of U.S. antitrust laws on industry joint ventures. The Commerce Department believes that there is a direct link between antitrust clarification for joint ventures and American firms' ability to compete globally in high-technology markets. Secretary Mosbacher recently testified on this issue before the Subcommittee on Economic and Commercial Law of the House Committee on the Judiciary.

Also, the Administration is studying programs aimed at developing broadcast and transmission standards that should enhance the timing and overall strategy for HDTV.

I should also indicate that Commerce is working with other agencies to develop further recommendations that are commensurate with the technical complexity, economic magnitude, and strategic implications that HDTV has. The Administration's activities to date have helped make both government and the private sector more aware of the potential importance to our economy of U.S. participation in HDTV development and we will continue to consult with the private sector to better understand our capabilities in this area.

Turning to the Congressional Budget Office report, I want to emphasize that we do not share its general pessimism about the promise of HDTV. On the other hand, both views must be somewhat speculative at this time, since no one really knows how large the ultimate HDTV market will be. However, I would like to note that the report is inaccurate in some areas.

Because of my business experience in the semiconductor industry, I will focus on this aspect of the report. On page 3 of its Executive Summary, the report states broadly:

> Even if domestic firms become the dominant suppliers [of HDTV sets], some components (semiconductors in particular) probably would be imported.

This suggests that the majority of semiconductor chips in sets made by U.S.-owned HDTV producers would likely be produced by foreign firms. I find this very unlikely. The only support given for this suggestion is the statement that although U.S. firms dominate the personal computer market, they buy "many" of their semiconductors from abroad. In fact, our semiconductor manufacturers maintain a very strong competitive position in supplying U.S. computer manufacturers. Forty percent of total U.S. semiconductor production goes into computers.

Compare this to the consumer electronics market, which is dominated by foreign companies who manufacture primarily in the United States. Their purchases of U.S. semiconductors represent only 7 percent of U.S. semiconductor sales. We conclude that U.S. participation in HDTV would yield substantial gains in U.S. semiconductor sales.

Also, the report implies that the problem with the U.S. DRAM sales during the 1980s resulted from a decrease in demand. The report failed to mention Japanese dumping of DRAMs, which drove all but one domestic producer out of this business.

In summary, I wish to contrast the thrust of this report, which downplays the commercial importance of HDTV, with the tangible commitment of the Japanese in this area. Their government and electronics industries have made vast capital investments in this field -- estimated in the billions of dollars already. Given the impressive record of the Japanese in selecting promising technologies for commercial development, it may not be prudent to underestimate the promise of HDTV.

Thank you Mr. Chairman and members of this committee for this opportunity. The Commerce Department and the Administration will work with Congress as we believe we share the same objectives and wish to achieve the same results.

TESTIMONY OF THE
AMERICAN ELECTRONICS ASSOCIATION
PRESENTED BY
TOM LONG
VICE PRESIDENT AND GENERAL MANAGER, TECHNOLOGY GROUP
TEKTRONIX, INC.
BEFORE THE
SENATE COMMITTEE ON GOVERNMENTAL AFFAIRS
AUGUST 1, 1989

MR. CHAIRMAN AND MEMBERS OF THE COMMITTEE, I AM TOM LONG, VICE PRESIDENT AND GENERAL MANAGER OF THE TECHNOLOGY GROUP AT TEKTRONIX, INC. IN BEAVERTON, OREGON. I APPEAR BEFORE YOU TODAY ON BEHALF OF THE AMERICAN ELECTRONICS ASSOCIATION TO DISCUSS THE CONGRESSIONAL BUDGET OFFICE REPORT ENTITLED "THE SCOPE OF THE HIGH-DEFINITION TELEVISION MARKET AND ITS IMPLICATIONS FOR COMPETITIVENESS."

THE AMERICAN ELECTRONICS ASSOCIATION (AEA) IS A 46 YEAR OLD NATIONAL NON-PROFIT TRADE ASSOCIATION OF SOME 3,500 COMPANIES AND 45 U.S. ENGINEERING UNIVERSITIES. OUR MEMBERS DESIGN, MANUFACTURE OR CONDUCT RESEARCH IN ELECTRONICS, ELECTRONIC COMPONENTS, AND RELATED INFORMATION TECHNOLOGY PRODUCTS.

TEKTRONIX IS A $1.4 BILLION CORPORATION ESTABLISHED IN 1946. WE ARE A LEADING MANUFACTURER OF ELECTRONIC PRODUCTS AND SYSTEMS IN THE AREAS OF TESTING AND MEASUREMENT, COMPUTER GRAPHICS, AND COMMUNICATIONS. IN FACT, TEKTRONIX SUPPLIES VIRTUALLY ALL TEST AND MEASUREMENT EQUIPMENT FOR HDTV. TEKTRONIX WAS ONE OF 36 AEA MEMBER COMPANIES THAT FUNDED THE DEVELOPMENT OF A BUSINESS PLAN TO ESTABLISH A U.S.-BASED HDTV INDUSTRY, AND I AM A MEMBER OF AEA's ADVANCED TELEVISION TASK FORCE.

CBO AND REALITY

THE CBO REPORT INTERPRETS THE SIGNIFICANCE OF HDTV MUCH TOO NARROWLY AND FAILS TO CONSIDER CLEAR TRENDS IN THE WORLD ELECTRONICS INDUSTRY. CBO ASSUMES THAT HDTV IS ONLY A TELEVISION TECHNOLOGY. ITS CONCLUSIONS, THAT THE SIGNIFICANCE OF HDTV IS UNCLEAR AND THAT HDTV WILL HAVE LITTLE IMPACT ON THE U.S. ELECTRONICS INDUSTRY, INEXPLICABLY CONTRADICT WHAT JAPAN, EUROPE, AND MOST U.S. TECHNICAL PEOPLE WHO HAVE STUDIED THE TECHNOLOGY KNOW. THE CBO's CONCLUSIONS ALSO FLY IN THE FACE OF ADVANCES IN IMAGING AND RELATED TECHNOLOGIES, AND THE WELL PLANNED, WELL FINANCED EFFORTS OF JAPANESE AND EUROPEAN FIRMS THAT ARE BETTING THEIR FUTURE ON HDTV, WITH CONSIDERABLE GOVERNMENT SUPPORT.

THE CBO's NARROW ACADEMIC EXERCISE COMPARING MARKET FORECASTS OF HDTV's IGNORES A PLETHORA OF DATA WHICH POINTS TO HDTV AS A DRIVER TECHNOLOGY AND FAILS TO ASCERTAIN THE TRUE DIMENSIONS OF THE INTERNATIONAL ELECTRONICS INDUSTRY. THERE ARE MANY REASONS WHY WE SHOULD DEVELOP A U.S.-BASED HDTV INDUSTRY. THE LEAST IMPORTANT OF THESE IS THE CENTRAL FOCUS OF THIS MISLEADING CBO REPORT: THE POTENTIAL MARKET FOR HDTV SETS. FAR MORE IMPORTANT IS THE FACT THAT THE HDTV INDUSTRY WILL HAVE AN IMPACT ON COMMERCIAL ELECTRONICS FOR FOUR PRIMARY REASONS:

- KEY COMPONENTS OF HDTVs (HIGH-RESOLUTION COLOR DISPLAYS AND VIDEO MEMORIES), WHICH MAKE UP ABOUT 50 PERCENT OF DIRECT COST, ARE ALSO KEY COMPONENTS OF ENGINEERING WORKSTATIONS AND HIGH-END PERSONAL COMPUTERS.

- o MANUFACTURING TECHNIQUES AND EQUIPMENT FOR SURFACE-MOUNT PRINTED CIRCUIT BOARDS AND SYSTEM FINAL ASSEMBLY WILL BE SHARED BY HDTVs AND COMPUTERS.

- o THE TIGHT ENGINEERING/MANUFACTURING LINKS THAT ENABLE FAST PRODUCT DEVELOPMENT, WHICH WERE LARGELY PIONEERED BY CONSUMER ELECTRONICS COMPANIES, ARE INCREASINGLY VITAL FOR COMMERCIAL ELECTRONICS COMPANIES AS LIFE CYCLES FOR MANY COMMERCIAL PRODUCTS SHRINK.

- o BEYOND THE YEAR 2000 HDTVs WILL BE A LARGE END-USE MARKET FOR INTEGRATED CIRCUITS (ICs) AND ESPECIALLY DIGITAL SIGNAL PROCESSING AND VIDEO MEMORY ICs. IF THE U.S. IC INDUSTRY LACKS THIS DOMESTIC MARKET, ITS DESIGN AND PROCESS SKILLS AND CASH FLOW WILL BE WEAKENED IN RELATION TO FOREIGN COMPETITION.

HDTV -- FUNDAMENTALLY DIFFERENT

EXPERIENCE OVER THE PAST DECADE IN EUROPE AND JAPAN HAVE BEEN THAT TECHNOLOGIES AND CAPABILITIES TRICKLE UP AS WELL AS TRICKLE DOWN. IN PARTICULAR, THE RAPID RATE OF PRODUCT AND TECHNOLOGY COMMERCIALIZATION AND THE RELENTLESS COST REDUCTIONS IN THE CONSUMER ARENA HAVE ENHANCED COMPANIES', AND THEIR SUPPLIERS', COMPETITIVENESS. HDTV PROMISES TO ACCELERATE THESE PATTERNS. PERHAPS EVEN MORE IMPORTANT IS THE FACT THAT HDTV ITSELF IS A FUNDAMENTALLY DIFFERENT PRODUCT FROM OTHERS IN THE CONSUMER FIELD: **IT HAS THE TECHNICAL CONTENT OF A COMPUTER OR WORKSTATION, BUT WILL ULTIMATELY HAVE THE HIGH VOLUMES ASSOCIATED WITH CONSUMER ELECTRONICS.**

AEA HAS SINGLED OUT HDTV FOR SUPPORT BY BOTH DARPA AND THE NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY BECAUSE IT IS A CRITICAL EMERGING TECHNOLOGY THAT WILL HAVE SIGNIFICANT IMPACT ON THE LONG-TERM HEALTH AND COMPETITIVENESS OF THE U.S. HDTV PRODUCTS WILL HAVE STRONG TECHNOLOGY AND ENGINEERING/ MANUFACTURING LINKS TO COMPUTER WORKSTATIONS AND A BROAD RANGE OF OTHER HIGH-RESOLUTION IMAGING BUSINESSES, AND WILL BE A MAJOR END-USE MARKET FOR SOPHISTICATED INTEGRATED CIRCUITS. A NUMBER OF CLOSELY-RELATED U.S. INDUSTRIES WILL BENEFIT FROM A STRONG U.S. HDTV INDUSTRY AND INFRASTRUCTURE. THESE INCLUDE COMPUTERS (WORKSTATIONS, PERSONAL COMPUTERS, GRAPHICS TERMINALS) THAT USE HDTV-LIKE COMPONENTS AND TECHNOLOGY IN THEIR DISPLAYS, MEMORIES, AND IMAGE PROCESSING; SEMICONDUCTORS, FOR WHICH THE HDTV INDUSTRY WILL BE A MAJOR MARKET IN THE LATE 1990s AND BEYOND; AND MANY COMMERCIAL/INDUSTRIAL HIGH-RESOLUTION IMAGINING BUSINESSES (E.G. ELECTRONIC PUBLISHING, MEDICAL IMAGING, COMPUTER-ASSISTED ENGINEERING, DRAFTING, MANUFACTURING) THAT DRAW ON THE HDTV COMPONENT AND TECHNOLOGY BASE.

IF THE U.S. ELECTRONICS INDUSTRY DOES NOT DEVELOP A STRONG TECHNOLOGY, ENGINEERING/MANUFACTURING INFRASTRUCTURE, AND VOLUME

POSITION IN HDTV PRODUCTS AND COMPONENTS, ITS COMPETITIVE POSITION IN COMMERCIAL (I.E. NON-CONSUMER) ELECTRONICS WILL BE UNDERMINED. ALTHOUGH THE HDTV PRODUCTS WILL NOT BECOME A MAJOR MARKET UNTIL AFTER THE YEAR 2000, THE INVESTMENTS MADE IN THE 1990s WILL DETERMINE WHO CONTROLS THE MARKET IN THE FOLLOWING DECADE.

CORRECTIONS FOR CBO

NOT ONLY IS CBO's FOCUS ON HDTV SETS MISPLACED, BUT MANY OF THE CONCLUSIONS CBO DRAWS FROM ITS ANALYSIS OF MARKET PROJECTIONS DONE BY THE AEA, THE ELECTRONICS INDUSTRY ASSOCIATION, AND THE DEPARTMENT OF COMMERCE ARE ERRONEOUS.

LET ME BE SPECIFIC.

o THE CBO REPORT IS FLAWED BY A LACK OF UNDERSTANDING OF THE DYNAMICS OF HOW THE ELECTRONICS AND INFORMATION TECHNOLOGY INDUSTRIES WORK. IN PARTICULAR TWO BASIC PREMISES OF THE REPORT ARE FAULTY:

1) IT LOOKS ONLY AT DOLLARS OF SALES OF SEMICONDUCTORS RATHER THAN AT NUMBER OF CHIPS TO BE USED IN HDTV AND CONCLUDES THAT MARKET SALES ARE TOO SMALL TO WARRANT GOVERNMENT INVOLVEMENT. THIS IGNORES THE REALITY THAT INCREASING NUMBERS OF CHIPS ARE BEING USED IN AN INCREASING MARKET FOR CONSUMER ELECTRONICS PRODUCTS. FOREIGN-DOMINATED CONSUMER ELECTRONICS MARKETS PURCHASE CHIPS FROM NON-U.S. MANUFACTURERS.

2) IT LOOKS AT HDTV DRAMs AS "JUST ANOTHER CHIP" AND IGNORES THE DRAM AS A "DRIVER TECHNOLOGY".

o CBO TAKES AEA DATA AS AN ECONOMETRIC STUDY. AEA's REPORT, HOWEVER, WAS DONE AS A "WORKING DOCUMENT" -- REFERRED TO AS SUCH TWICE (p. iii in the Forward and under caption "A Working Document Approach" on p. I-1 of Section I):

> "Since it is impossible to know when HDTV's "ripple effect will occur (i.e., what new product spin-offs may erode market share in non-consumer electronics fields), quantifying market impact requires extensive time and resources beyond those of the AEA HDTV Task Force. This "working document," therefore, will be modified as other studies bring information to bear on it. AEA's Board of Directors has called for third party studies on the subject -- one by the National Research Council and one by the National Academy of Engineering. In the meantime, the information is offered to indicate trends of impact or the best judgment of experts."

PERHAPS THIS COMMITTEE, IN ITS ATTEMPT TO EXPLORE ALL

VIEWPOINTS ON HDTV, COULD ASSIST IN PLACING THIS ISSUE ON THE AGENDA OF THE NRC AND NAE FOR THEIR EXPERT CONSIDERATION. ALTHOUGH A SCIENTIFIC STUDY OF HDTV BY THE ACADEMIES MAY NOT ATTRACT THE PRESS ATTENTION THAT CBO's REPORT HAS, I BELIEVE IT WOULD GREATLY CONTRIBUTE TO OUR UNDERSTANDING OF THIS COMPLICATED, BUT CRITICAL ISSUE.

NO ONE ELSE IN THE U.S. HAS UNDERTAKEN A "RIPPLE" EFFECT STUDY NOR SO FAR SEEMS WILLING TO DO SO FOR LESS THAN SIX MONTHS LEADTIME AND $100,000. ANYONE CAN DISPUTE FORECASTS BECAUSE ONLY TIME WILL OFFER VALIDITY OR REPUDIATION. IT IS ESPECIALLY FAULTY, HOWEVER, TO DISPUTE THEM WITHOUT ANOTHER STUDY TO COMPARE. IN THE ABSENCE OF ANOTHER STUDY, CBO'S ANALYST USES HIS OWN SECOND HAND KNOWLEDGE OF HOW TODAY'S ELECTRONICS INDUSTRY WORKS TO DISPUTE THE THINKING OF SOME 50 INDUSTRY TECHNOLOGISTS AND ANALYSTS. HE DOES NOT TAKE INTO ACCOUNT THE UNIVERSE OF KNOWLEDGE GENERATED BY THE SOME 24 REPORTS PROVIDED REPRESENTATIVE MARKEY IN FEBRUARY, JAPANESE MARKET PROJECTIONS AND INVESTMENTS, ETC.

o THE CBO REPORT ERRONEOUSLY STATES THAT AEA DOES NOT INCLUDE ITS METHODOLOGY IN ITS REPORT. See AEA Report, Section III, p. 2, relative to the "ripple effect" of HDTV on semiconductors, personal computers, and automated manufacturing equipment:

"Tables 9, 10, 11 figures were derived by first collecting perspectives of HDTV impact on U.S. marketshare by the year 2010 from experienced industry analysts and company executives, averaging them, and then phasing in the impact on an equal basis each year beginning in 1991."

EXCERPTS FROM CHAPTER 1 OF THE CBO REPORT

o "BY CONTRAST, THE MARKET FORECASTS REVIEWED IN THIS REPORT SEE HDTV AS AN INSTANT SUCCESS" (Page 2, Paragraph 2) THIS IS AN INCORRECT ASSUMPTION ON CBO'S PART. (See page 2-8 of the AEA Report) AEA ASSUMES HDTV RECEIVERS WILL BEGIN TO BE SOLD IN U.S. IN 1996 AND ONLY SLOWLY BE SUCCESSFUL:

AEA REPORT--HDTV UNITS SOLD·

1996	100,000 UNITS
1997	100,000 UNITS
1998	300,000 UNITS
1999	500,000 UNITS
2000	1 MILLION UNITS

THIS IS HARDLY AN INSTANT SUCCESS AND ASSUMES TECHNOLOGICAL ADJUSTMENTS, ETC. EIA, ON THE OTHER HAND, MAKES AGGRESSIVE UNIT SALES PROJECTIONS AND PERHAPS ASSUMES INSTANT SUCCESS. AEA CLEARLY DOES NOT.

o "HOWEVER, EVEN IF DOMESTIC FIRMS BECOME THE DOMINANT SUPPLIERS, SOME COMPONENTS (SEMICONDUCTORS IN PARTICULAR) PROBABLY WOULD BE IMPORTED" (Page 3, Paragraph 1) EIA's REPORT CLEARLY STATES THAT EVEN OVER THE NEXT DECADE, 15 PERCENT OF HDTV ELECTRONIC COMPONENTS WILL BE IMPORTED. CBO'S USE OF THE WORD PROBABLY RUNS COUNTER TO PAST AND PRESENT PRACTICE AND STATED FUTURE PRACTICE BY THOSE "INSIDERS" IN THE U.S. TV INDUSTRY--TO PURCHASE COMPONENTS, SEMICONDUCTORS IN PARTICULAR, FROM FOREIGN SUPPLIERS.

o "EVEN THE OPTIMISTIC FORECASTS OF THE POTENTIAL SIZE OF THE HDTV MARKET ARE SMALL RELATIVE TO THE OTHER MARKETS IN THE ELECTRONICS SECTOR. THUS, IT IS UNLIKELY THAT HDTV WILL PLAY A PIVOTAL ROLE IN THE COMPETITIVENESS AND TECHNOLOGY DEVELOPMENT OF THE SECTOR AS A WHOLE" (Page 3, Paragraph 2) THIS IS A CENTRAL CBO FAULTY PREMISE THAT INCORRECTLY FOCUSES ON HDTV DOLLAR SALES RATHER THAN UNDERSTANDING THE ISSUE IS UNITS OF SEMICONDUCTORS AND DRIVER TECHNOLOGY OF DRAMS THAT ARE AT ISSUE.

o "ONE FORECAST THAT DEALT WITH THE QUESTION OF MARKET LINKAGES ASSUMED ITS RESULTS AND PROVIDED NO SPECIFIC EVIDENCE" (Page 3, Paragraph 2) SEE SECTIONS OF AEA's REPORT RELATING TO SEMICONDUCTORS (Pages 3-8 and 3-9) FOR A LENGTHY DISCUSSION OF HOW SEMICONDUCTOR TECHNOLOGY IN HDTV WILL IMPACT LEARNING CURVES, ETC. AND MARKET SHARE IN COMPUTERS, ETC.

o "U.S.-BASED ELECTRONICS MANUFACTURING FIRMS MAY GAIN OR LOSE MARKET SHARE IN THE NEXT 20 YEARS, BUT THEY ALREADY HAVE MANY INCENTIVES TO MAINTAIN THEIR COMPETITIVENESS AND A LARGE ENOUGH MARKET IN WHICH TO ENJOY ECONOMIES OF SCALE" (Page 3, Paragraph 2) THIS IS AN EXTREMELY NARROW VIEW OF HOW ONE GAINS OR LOSES MARKET SHARE; IT DENIES HISTORY AND THE MANY SITUATIONS OF MARKET SHARE THE U.S. ONCE DOMINATED AND THEN LOST--MOTORCYCLES, TELEVISIONS, VCRS, AUTOS, STEPPERS, DRAMS, ETC.

o "IT SEEMS COUNTERINTUITIVE TO SUGGEST THAT A SMALL MARKET THAT MAY EXIST IN THE FUTURE IS A MORE IMPORTANT DRIVER OF ECONOMIES OF SCALE, TECHNOLOGY, AND COMPETITIVE SUCCESS THAN IS THE GROWTH IN THE PRESENT MARKET" (Page 4, Paragraph 1) IT MAY BE "COUNTERINTUITIVE" BUT IT IS "COUNTER-EXPERIENCE" NOT TO ASSUME THE POSSIBILITY. JAPANESE ENTER SMALL, FRINGE, LOW-END MARKET SEGMENTS AND MOVE UP OVER TIME INTO LARGE, CORE, HIGH-END MARKETS TO DRIVE MAJOR COMPETITORS OUT. SEE HARVARD BUSINESS REVIEW, MAY-JUNE 1989, "STRATEGIC INTENT," GARY HAMEL AND C. K. PRAHALAD.

EXCERPTS FROM CHAPTER 2 OF THE CBO REPORT

- "THE EIA REPORT CONCLUDES THAT SALES OF HDTV COULD REACH 13.1 MILLION UNITS BY 2003, RAISING INCOME AND EMPLOYMENT IN THE ELECTRONICS SECTOR, REGARDLESS OF WHETHER THE MARKET IS SUPPLIED BY FOREIGN-OR-DOMESTIC-BASED PRODUCERS" (Page 2, Paragraph 1) CBO IGNORED EIA REPORT WHICH SAYS THAT TODAY'S EQUIVALENT NUMBERS OF TV WORKERS WILL SIMPLY SWITCH FROM PRODUCING COLOR TVS TO PRODUCING HDTVS INT THE FUTURE AND, THEREFORE, THERE WILL "BE NO NET GAIN OR LOSS" OF JOBS DUE TO HDTV.

- "ALL FORECASTS BUT DARBY'S LOW-GROWTH SCENARIO SUGGEST THAT THE MARKET VALUE OF HDTV SALES WILL GROW RAPIDLY" (Page 5, Paragraph 1) (See CBO Report, Figure 2) AEA'S GROWTH IS SIGNIFICANTLY SLOWER COMPARED TO OTHERS, ESPECIALLY BETWEEN 1996 - 2000.

- "CBO MAKES NO ATTEMPT, HOWEVER, TO PROVIDE AN ALTERNATIVE FORECAST" (Page 6, Paragraph 2) UNLESS YOU CAN PROVE ASSUMPTIONS IN A FORECAST ARE FAULTY OR UNLESS YOU OFFER AN ALTERNATIVE FORECAST, AN ANALYSIS CRITICAL TO FORECASTS ARE OPEN TO CONJECTURE.

- "THE FORECASTS SHARE TWO CRITICAL ASSUMPTIONS--THAT HDTV WILL BE A SUCCESS WITH CONSUMERS, AND THAT THE MARKET WILL GROW RAPIDLY FROM THE OUTSET" (Page 7, Paragraph 1) CBO SIMPLY KEEPS REPEATING THIS ERRONEOUS STATEMENT. AEA'S ASSUMPTION IS THAT CONSUMERS ARE PRICE-SENSITIVE AND THAT ONLY AS TECHNOLOGICAL BREAKTHROUGHS DRIVE THE RETAIL PRICE DOWN WILL CONSUMERS BUY IN INCREASING NUMBERS.

- "ANOTHER ASSUMPTION COMMON TO ALL FORECASTS IS THAT HDTV MANUFACTURERS ARE GOING TO "GET IT RIGHT"--THAT IS, PRODUCE THE EXACT PRODUCT CONSUMERS WANT--THE FIRST TIME" (Page 11, Paragraph 1) CBO MAKES A GREAT LEAP TO ASSUME THIS IS AEA'S ASSUMPTION; WE NOT ONLY NEVER STATE IT AS SUCH BUT WE ASSUME THE OPPOSITE--I.E., THAT TECHNOLOGICAL REFINEMENTS WILL CHANGE AND ENHANCE THE PRODUCT TO MAKE IT INCREASINGLY ATTRACTIVE IN QUALITY AND, THEREFORE, INCREASE CONSUMER DEMAND OVER TIME.

EXCERPTS FROM CHAPTER 2 OF THE CBO REPORT

- "IN MOST CASES, CBO FOUND THAT THE ABILITY OF POTENTIAL SUPPLIERS OF SEMICONDUCTORS, FLAT-PANEL DISPLAYS, AND COMPUTERS TO COMPETE IN INTERNATIONAL MARKETS WOULD NOT IN ALL LIKELIHOOD BE DETERMINED BY THE SUCCESS OR FAILURE OF THE HDTV MARKET. RATHER, CHANGES IN U.S. MARKET SHARE IN MOST OF THE SUPPLIER MARKETS ARE MORE LIKELY TO RESULT FROM THE ACTIONS OF FIRMS AND THE DEVELOPMENT OF TECHNOLOGIES WITHIN THOSE MARKETS THAN FROM PRESSURES OR ADVANTAGES CREATED BY HDTV" (Page 1, Paragraph 2) CBO DOES NOT UNDERSTAND THE INTER-RELATIONSHIP BETWEEN SEGMENTS

OF THE ELECTRONICS INDUSTRY AND THEIR VARIOUS MARKETS. CBO SEEMS TO IMPLY IN ITS REFERENCE TO "ACTIONS OF FIRMS" THAT THESE WILL BE MUTUALLY EXCLUSIVE TO PRESSURES OR ADVANTAGES CREATED BY HDTV.

o "THUS, THE TECHNICAL ADVANTAGE [FOREIGN ADVANTAGE IN DISPLAY TECHNOLOGY] WOULD HAVE TO BE GREAT, THOUGH AEA OFFERS NO EVIDENCE THAT SUCH AN ADVANTAGE WOULD OCCUR" (Page 7, Paragraph 1) CBO TRIES TO DEAL WITH FORECASTS AS IF THEY WERE HISTORY, BASING ITS CRITICISMS ON A LACK OF "EVIDENCE." NO ONE HAS EVIDENCE OF A FUTURE EVENT. AND GIVEN THE AMOUNT OF R&D DOLLARS BOTH JAPANESE GOVERNMENT AND ITS INDUSTRY HAVE RECENTLY COMMITTED TO DISPLAYS, AEA'S PREDICTION THAT FOREIGN COMPANIES WILL HAVE AN ADVANTAGE IN DISPLAYS SEEMS EVEN MORE REASONABLE TODAY THAN A YEAR AND A HALF AGO WHEN THE AEA REPORT CAME OUT.

o "A MARKET AS SMALL AS THAT FORECAST FOR HDTV IS NOT LIKELY TO AFFECT SUBSTANTIALLY THE U.S. MARKET SHARE IN COMPUTERS, COMMUNICATIONS EQUIPMENT, AND OTHER ELECTRONIC EQUIPMENT. THESE MARKETS ARE ALREADY LARGE AND CONTINUE TO GROW RAPIDLY. . . . OTHER ELECTRONICS INDUSTRIES ARE ALREADY MUCH LARGER AND ARE LIKELY TO CONTINUE TO GROW AT A SIGNIFICANT PACE OVER THE NEXT DECADES" (Page 7, Paragraph 2) SEE ATTACHMENT FROM ELECTRONICS INDUSTRY ASSOCIATION OF JAPAN WHICH SHOWS WORLDWIDE PRODUCTION OF ELECTRONICS PRODUCTS OF THE U.S. AS DROPPING FROM 50.4 PERCENT IN 1984 TO 39.7 PERCENT IN 1987, WHILE THAT OF JAPAN ROSE FROM 21.3 PERCENT TO 27.1 PERCENT IN THE SAME TIMEFRAME. THE TREND IS DECREASED GROWTH FOR U.S. ELECTRONICS PRODUCTS.

PRIOR TO 1970, THE U.S. HELD NEAR 100 PERCENT OF THE WORLD MARKET IN AUTOMATED MANUFACTURING EQUIPMENT; TODAY IT HOLDS 35 PERCENT.

IN 1983, THE U.S. HAD 72.4 PERCENT OF THE WORLD WIDE MARKET SHARE IN PERSONAL COMPUTERS; BY 1987 U.S. SHARE HAD DROPPED TO 69.1 PERCENT. IN 1988 JAPAN AND KOREA INCREASED THEIR WORLD WIDE MARKET SHARE IN PCS BY 3.4 PERCENT AT THE EXPENSE OF U.S. IBM AND APPLE.

IN 1984 U.S. HAD 50 PERCENT OF WORLDWIDE SEMICONDUCTOR MARKET AND JAPAN HAD 33 PERCENT; BY 1988 U.S. SHARE HAD DROPPED TO 31 PERCENT AND JAPAN'S HAD INCREASED TO 39 PERCENT.

SEE ATTACHMENT "WORLD SHARE OF DRAMS:" IN 1975 U.S. HAD 95.8 PERCENT OF WORLD SHARE OF DRAMS AND JAPAN HAD 4.5 PERCENT; 12 YEARS LATER, THE U.S. HAS 17.9 PERCENT OF WORLD SHARE OF DRAMS BUT JAPAN HAS 73.0 PERCENT.

SEE ATTACHMENT FROM SILICON VALLEY GROUP, INC. OF U.S. SHARE OF WORLDWIDE ELECTRONICS PRODUCT MARKETS BETWEEN 1984 AND 1987: IN 25 INDUSTRY PRODUCT AREAS, THE U.S. SHARE WENT DOWN IN ALL BUT TWO--SOFTWARE AND OS (OPERATING SYSTEMS).

- "SECOND, NEITHER THE MEMORY DEVICES NOR THE DIGITAL SIGNAL PROCESSORS--THE MOST COMMON TYPES OF INTEGRATED CIRCUIT USED IN HDTV--ARE MORE SOPHISTICATED THAN THOSE CURRENTLY PRODUCED BY THE SEMICONDUCTOR INDUSTRY" (Page 11, Paragraph 2) NOT TRUE. DIGITAL SIGNAL PROCESSING TECHNOLOGY IS A KEY FOCUS FOR U.S. HDTV R&D ACCORDING TO A STUDY BY THE BOSTON CONSULTING GROUP. CBO MAY HAVE I.T.T. IN MIND IN THE REFERENCE TO INTEGRATED CIRCUITS USED IN HDTV; IF SO, I.T.T PRIMARILY PRODUCES ITS CHIPS IN EUROPE FOR A EUROPEAN TV MARKET, FORCED TO DEPRIVE THE U.S. OF EVEN A TECHNOLOGICAL BASE FOR DSP DESIGN, MANUFACTURE, ETC.

SEE ATTACHED "STATUS AND TRENDS OF U.S. SEMICONDUCTOR TECHNOLOGY RELATIVE TO JAPAN;" JAPAN IS LEADING THE U.S. IN 12 AREAS; THE U.S. AND JAPAN HAVE PARITY IN TECHNOLOGY IN NINE AREAS BUT THE U.S. IS SLIPPING IN PARITY IN THREE OF THESE; THE U.S. IS LEADING JAPAN IN SEMICONDUCTOR TECHNOLOGY IN FOUR AREAS, WITH ALL BUT ONE--I.E., LINEAR, WHICH IS DECLINING.

- "THIS LEAD IN DESIGN INNOVATION [BY U.S.] IS LONG-STANDING AND CUTS ACROSS MANY PRODUCT CATEGORIES. IT SEEMS UNLIKELY THAT ONE PROGRAM COULD REVERSE THIS LONG-STANDING ADVANTAGE" (Page 12, Paragraph 1) CBO'S ASSUMPTION THAT U.S. IS INDOMITABLE IN DESIGN IS NOT COMFORTING. THE NUMBER OF U.S. ENGINEERS WITH DESIGN CAPABILITY IN CONSUMER ELECTRONICS HAS EBBED SIGNIFICANTLY OVER THE LAST 15 TO 20 YEARS AS WE MOVED OUT OF CONSUMER ELECTRONICS PRODUCT MANUFACTURING. NEW U.S. ENGINEERING GRADUATES ARE NOT STUDYING CONSUMER PRODUCT DESIGN OR APPLICATIONS--NO FACULTY, NO EQUIPMENT, NO JOBS AFTER GRADUATION.

- "IF HDTV CAUSES A SUBSTANTIAL EXPANSION IN DEMAND FOR DRAMS, THIS ADDITIONAL DEMAND IS MOST LIKELY TO GO TO FIRMS THAT ALREADY MANUFACTURE THEM" (Page 13, Paragraph 2) CBO IS CORRECT IF NOTHING CHANGES THE PRESENT SITUATION. CHANGING THE SITUATION IS THE BASIS FOR WHY THE BOSTON CONSULTING GROUP'S AEA-HDTV STRATEGY PLAN INCLUDES INCENTIVES FOR U.S. HDTV MANUFACTURERS TO BUY U.S. PRODUCED SEMICONDUCTORS. UNLESS THERE IS AN INCENTIVE FOR SUCH PURCHASE, FOREIGN COMPANIES WITHIN THE U.S. WILL PREDICTABLY CONTINUE AS THEY HISTORICALLY HAVE DONE--I.E., TO PURCHASE DRAMs FROM FOREIGN SOURCES.

- "FURTHERMORE, AEA'S SALES PROJECTION ASSUMES THAT HDTV PRICES WILL BE WELL BELOW $1,000 PER MACHINE; WHEREAS THE AVERAGE PRICE OF THE IBM-COMPATIBLE PERSONAL COMPUTER IS WELL ABOVE THAT" (Page 18, Paragraph 2) CBO MISSED AEA REPORT, SECTION II, PAGE 4, WHERE AEA PRICE ASSUMPTIONS ARE CLEARLY STATED. AEA INDICATES THAT NOT UNTIL 17 YEARS OUT DO WE ASSUME A RETAIL PRICE PER MACHINE OF LESS THAN $1000.

ALSO SEE AEA REPORT, PAGE III-4:

YEAR	PRICE PER MACHINE
1990	$4,000
1995	$2,500
2000	$1,500
2005	$ 800

HDTV: LINCHPIN OF AN INFORMATION TECHNOLOGY

IN A RECENT STUDY BY JAPAN'S MINISTRY OF INTERNATIONAL TRADE AND INDUSTRY (MITI) IT WAS ESTIMATED THAT BY THE YEAR 2000, ONE-THIRD OF JAPAN'S GNP WOULD COME FROM ELECTRONICS AND INFORMATION INDUSTRIES, TRIPLE THE PERCENT OF 1984. JAPAN'S MINISTRY OF POSTS AND TELECOMMUNICATIONS PROJECTS ESTIMATES THAT HDTV RELATED SALES IN JAPAN WILL TOTAL $100 BILLION (US $) BY THE YEAR 2000 (SEE ATTACHMENT). THIS REPRESENTS AN ENORMOUS COORDINATED EFFORT BY JAPANESE FIRMS AND GOVERNMENT AGENCIES TO BUILD A NEW "INFORMATION ECONOMY" AROUND HDTV THAT WILL BE UNRIVALED.

AS EXPLAINED BY AEA's CONSULTANT ROBERT COHEN IN THE ATTACHED PAPER, ONE ILLUSTRATION OF HOW THIS TRANSFORMATION TO AN INFORMATION ECONOMY HAS ALREADY BEGUN TO AFFECT U.S. ELECTRONICS FIRMS IS THE RECENT SIZABLE INCREASE IN SEMICONDUCTOR CONSUMPTION BY JAPAN. AS SHOWN IN TABLE 1, BETWEEN 1984 AND 1989, JAPAN IS EXPECTED TO MORE THAN DOUBLE ITS CONSUMPTION OF SEMICONDUCTORS, WITH THE COMPUTER AND COMMUNICATIONS INDUSTRIES CONSUMING OVER THREE TIMES THEIR EARLIER LEVEL AND THE CONSUMER ELECTRONICS SECTOR NEARLY DOUBLING ITS CONSUMPTION. THE U.S. FIGURES SHOW MUCH LOWER RATES OF GROWTH. IF THE CONSUMER MARKET IN JAPAN IS THE DRIVER OF ITS MASS-MARKET STRENGTH, IT IS NOW EXPECTED TO BE NEARLY THREE TIMES THE SIZE OF THE U.S. MILITARY'S CONSUMPTION OF "CHIPS", WITH THE MILITARY PURCHASES USUALLY SEEN AS THE MAIN TECHNOLOGY DRIVER IN U.S. INDUSTRY.

TABLE 1

SEMICONDUCTOR CONSUMPTION IN JAPAN AND THE U.S., 1984 AND 1989
(BILLIONS OF DOLLARS)

JAPAN	1984	1989
COMPUTERS	3.15	9.62
TELECOMMUNICATIONS	1.03	3.04
CONSUMER ELECTRONICS	3.39	5.78
TOTAL	8.77	21.3
U.S.		
COMPUTERS	6.02	7.99
TELECOMMUNICATIONS	2.03	2.46
CONSUMER ELECTRONICS	0.97	1.05
MILITARY	1.27	1.97
TOTAL	13.14	17.43

A CRITICAL DEFECT IN THE CBO REPORT IS ITS ASSUMPTION THAT HDTV WILL NOT BE SIGNIFICANT SINCE ITS IMPACT ON THE WORLD SEMICONDUCTOR INDUSTRY WILL BE MINUSCULE. FIGURE 4 OF THE CBO REPORT COMPARES THE CONSUMPTION OF SEMICONDUCTORS IN HDTVs BUILT IN THE U.S. IN THE YEAR 2010 -- ESTIMATED AT $682 MILLION BASED ON FIGURES IN THE AEA STUDY -- WITH TOTAL WORLD SALES OF SEMICONDUCTORS IN 2010, WHICH ARE ESTIMATED TO BE $303 BILLION. SINCE THE CONSUMPTION OF CHIPS IN HDTV IS SO SMALL, THE CBO REPORT CONCLUDES THAT IT IS IMPLAUSIBLE FOR IT TO HAVE MUCH OF AN IMPACT ON THE SEMICONDUCTOR INDUSTRY, ESPECIALLY TO CREATE THE SIGNIFICANT DIFFERENCES IN THE SHARES OF U.S. MANUFACTURERS IN THE WORLD SEMICONDUCTOR MARKET.

AS COHEN POINTS OUT, THE COMPARISON MADE BY THE CBO REPORT BETWEEN THE CONSUMPTION OF CHIPS IN U.S.-MADE HDTVs AND THE WORLD MARKET FOR CHIPS IS DISINGENUOUS. IT OBFUSCATES THE REAL ARGUMENT MADE BY MANY EXPERTS WHO PARTICIPATED IN THE THREE STUDIES BEING EVALUATED, NAMELY, THAT STRENGTHENING THE U.S. HDTV INDUSTRY WOULD PROVIDE A NEW DYNAMICS TO SIGNIFICANT PARTS OF THE ELECTRONICS SECTOR BY INVIGORATING THOSE PARTS OF THE INDUSTRY THAT ARE DRIVEN PRIMARILY BY MARKET FORCES.

> COHEN STATES: "SINCE THE CONSUMER ELECTRONICS SECTOR IS THE MAIN PART OF THE ELECTRONICS INDUSTRY THAT WOULD BE AFFECTED BY INITIATIVES IN HDTV, A FAIRER COMPARISON WOULD BE TO JUDGE HOW SUBSTANTIAL THE CONSUMPTION OF SEMICONDUCTORS FOR HDTV WOULD BE IN 2010 COMPARED TO THE CONSUMPTION OF SEMICONDUCTORS IN THE U.S. CONSUMER ELECTRONICS INDUSTRY IN 2010. USING ESTIMATES OF THE TOTAL U.S. MARKET FOR SEMICONDUCTORS FROM THE AEA REPORT TO PROJECT SUCH CONSUMPTION FROM THE DATAQUEST FIGURES IN TABLE 2, SHOW THAT

> THE $682 MILLION CONSUMPTION OF CHIPS IN 2010 WOULD BE NEARLY 10 PERCENT OF THE TOTAL DEMAND FOR SEMICONDUCTORS BY CONSUMER ELECTRONICS FIRMS. INDEED, INCLUDING THE FIGURE FOR CHIP DEMAND BY 12 MILLION EDTV SETS THAT THE AEA STUDY ESTIMATES WOULD BE SOLD IN THIS YEAR WOULD BE LIKELY TO NEARLY DOUBLE THE DEMAND FOR CHIPS, MAKING IT REASONABLE TO ARGUE THAT INITIATIVES TO INVIGORATE THE U.S. TV INDUSTRY WOULD BE LIKELY TO ACCOUNT FOR APPROXIMATELY 20 PERCENT OF THE DEMAND FOR SEMICONDUCTORS IN 2010." (SEE TABLE 2)

THEREFORE, IT IS CERTAINLY PLAUSIBLE TO ARGUE, AS THE EXPERTS WHO DEVELOPED THE AEA STUDY HAVE, THAT THERE WOULD BE DRAMATIC DECLINES IN THE WORLD MARKET SHARES OF THE U.S. SEMICONDUCTOR INDUSTRY IF KEY NEW PRODUCT MARKETS DO NOT BECOME AN INTEGRAL PART OF THE U.S. ELECTRONICS INDUSTRY.

DYNAMIC RANDOM ACCESS MEMORY (DRAM)

COHEN'S RESPONSE TO CBO ALSO DISCUSSES THE CRITICAL LINKAGES BETWEEN HDTV AND DRAMS AND FLAT PANEL DISPLAYS. DRAMs ARE A WIDELY ACKNOWLEDGED "TECHNOLOGY DRIVER" SINCE DRAM PRODUCTION PROCESSES LEAD THOSE FOR OTHER TYPES OF CHIPS BY 18 TO 24 MONTHS. THE LOGIC FOLLOWED IN THE CBO STUDY FAILS TO CONSIDER THE OUTCOMES THAT MAY BE REACHED IF NEARLY ALL OF THE LARGE JAPANESE AND EUROPEAN FIRMS PARTICIPATE IN THE DEVELOPMENT OF HDTV AND RELATED TECHNOLOGIES. BY WEAKENING THEIR BASE IN DRAMs AND LOSING OUT ON THE RACE TO DEVELOP COMMERCIAL HDTV, THE U.S. ELECTRONICS INDUSTRY COULD BE CONSIDERABLY WEAKENED RELATIVE TO ITS COMPETITORS.

FLAT-PANEL DISPLAYS

ANOTHER PROBLEM WITH THE CBO STUDY IS ITS MISUNDERSTANDING OF THE CONNECTION BETWEEN FLAT-PANEL DISPLAYS AND HDTV. THE DEVELOPMENT OF FLAT-PANEL DISPLAYS IS EXPECTED TO BE A TECHNOLOGY DRIVER SINCE IT REQUIRES NEW SKILLS IN FABRICATION OF VERY LARGE SEMICONDUCTOR ARRAYS ON GLASS. WHILE COLOR FLAT PANEL DISPLAYS WILL SOON BE INCLUDED IN PORTABLE COMPUTERS, THE REAL COMMERCIAL MARKET FOR SUCH DISPLAYS WILL BE IN LARGE TV SCREENS, WITH OVER 40-INCH DIAGONAL DISPLAYS.

IN MAY OF 1989, PHOTONICS, A FIRM BASED IN NORTHWOOD, OHIO, DEMONSTRATED A 17 INCH FLAT-PANEL COLOR VIDEO MONITOR AND HAS PROPOSED TO DELIVER TO DARPA IN 1991 A LOW-COST 50 INCH FLAT-PANEL COLOR MONITOR THAT IS HDTV COMPATIBLE AND CAN HANG ON THE WALL LIKE A PICTURE. THIS IS FIVE YEARS EARLIER THAN JAPAN'S PROJECTED PRODUCTION OF A 40 INCH FLAT-PANEL DISPLAY. THE EXECUTIVE VICE PRESIDENT OF PHOTONICS, DR. PETER FRIEDMAN, BELIEVES THAT "THE INTRODUCTION OF LARGE SCREEN FLAT-PANEL HDTV WILL CREATE A U.S. MARKET ON THE ORDER OF $30 BILLION BEFORE THE END OF THE 1990's."

TABLE 2

ESTIMATED SEMICONDUCTOR CONSUMPTION IN JAPAN AND THE U.S. 1992 AND 2010 (IN BILLIONS OF 1988 DOLLARS)

JAPAN	1992	2010
COMPUTERS	14.5	73.
TELE-COMMUNICATIONS	4.6	23.
CONSUMER ELECTRONICS	7.0	35.
ALL CATEGORIES	30.5	150.

UNITED STATES		
COMPUTERS	12.0	60.
TELE-COMMUNICATIONS	3.3	16.5
CONSUMER ELECTRONICS	1.36	7.0
MILITARY	2.45	12.5
ALL CATEGORIES	24.99	125.

SOURCE: DATAQUEST FOR 1992 AND AUTHOR'S FIGURES BASED ON AEA STUDY ESTIMATES FOR 2010.

FOREIGN COMPETITION

OTHER IMPORTANT ELEMENTS OF THE HDTV MARKET THAT WERE OVERLOOKED BY CBO, ARE THE ACTIVITIES OF OUR FOREIGN COMPETITORS. DEVELOPMENT OF HDTV INDUSTRIES IN EUROPE AND JAPAN WILL OCCUR IN THE 1990s BECAUSE EUROPE AND JAPAN BOTH HAVE STRONG, WELL-ORGANIZED PLANS TO MAKE HDTV PROGRAMMING AVAILABLE AND TO PROMOTE (AND IN SOME CASES SUPPORT) THE PURCHASE OF HDTV HARDWARE.

NHK, THE JAPANESE NATIONAL BROADCASTING COMPANY, WILL BEGIN BROADCASTING HDTV PROGRAMS VIA SATELLITE FOR THREE HOURS PER DAY IN JULY 1989; THE SCHEDULE WILL GRADUALLY INCREASE. A PROGRAM IS PLANNED TO USE JAPAN DEVELOPMENT BANK FUNDS TO FINANCE THE PURCHASE BY REGIONAL AND MUNICIPAL GOVERNMENT BODIES OF HDTV RECEIVERS FOR SHOWCASE APPLICATIONS, AND THE JAPANESE MANUFACTURERS WILL AGGRESSIVELY DEVELOP SHOWCASE APPLICATIONS IN PUBLIC PLACES. NHK HAS SPENT OVER $500 MILLION ON DEVELOPMENT OF THE JAPANESE HDTV TECHNOLOGY AND STANDARDS, AND JAPANESE COMPANIES HAVE SPENT AT LEAST $400 MILLION OF THEIR OWN FUNDS ON PRODUCT DEVELOPMENT. THE ATTACHED "HDTV MANDALA" FROM JAPAN DEMONSTRATES HOW JAPAN VIEWS HDTV AS THE FOCAL POINT FOR A WIDE RANGE OF TECHNOLOGIES.

ANOTHER RELATED JAPANESE EFFORT WORTH NOTING IS THEIR SO-CALLED "GIANT ELECTRONICS" PROGRAM. JAPAN'S MINISTRY OF INTERNATIONAL TRADE AND INDUSTRY (MITI) HAS LAUNCHED A GIANT ELECTRONICS PROGRAM TO DEVELOP VARIOUS FUNDAMENTAL TECHNOLOGIES NEEDED TO REALIZE 1-METER SQUARE DISPLAY CIRCUIT ELEMENTS WITHIN SEVEN YEARS. THESE ULTRA-THIN, LARGE DISPLAY ELEMENTS WILL BE USED IN BOOK-SIZE COMPUTERS, OPTICAL PUBLISHING AND OTHER INNOVATIONS. (SEE ATTACHMENT)

EUROPE PLANS TO REBUILD ITS ENTIRE BROADCASTING INFRASTRUCTURE AROUND HDTV THROUGH A PROGRAM CALLED TELEVISION WITHOUT FRONTIERS THAT WILL CREATE A NEW, HIGH-DEFINITION, SATELLITE-BASED SYSTEM. ORGANIZATIONS APPLYING TO USE THE NEW SATELLITE CHANNELS MUST SIGN ON TO A PROGRAM THAT MOVES IN THREE STAGES TO A TRUE HIGH-DEFINITION SYSTEM BY 1992. HIGH-DEFINITION COVERAGE OF THE 1992 BARCELONA SUMMER OLYMPICS IS PLANNED AS THE KICK-OFF FOR HIGH-DEFINITION BROADCASTING IN EUROPE. THE EUROPEAN INDUSTRY, WITH GOVERNMENT SUPPORT, HAS SPENT SEVERAL HUNDRED MILLION DOLLARS ON DEVELOPMENT OF THE EUROPEAN HIGH-DEFINITION TECHNOLOGY (MAC) THROUGH A SUBGROUP OF THE EUREKA ORGANIZATION.

U.S. LAGGING BEHIND

THE U.S. IS SIGNIFICANTLY BEHIND JAPAN AND EUROPE IN THE QUALITY OF ITS INFRASTRUCTURE. SUCCESS IN CONSUMER ELECTRONICS IS DRIVEN BY RAPID AND INNOVATIVE DESIGN CAPABILITIES; FLEXIBLE, HIGH-QUALITY, AND LOW-COST PLANTS; AND TIGHT, CLOSE LINKS BETWEEN

THESE TWO. HISTORICALLY, U.S.-BASED COMPANIES HAVE BEEN LESS SUCCESSFUL THAN OBSERVED JAPANESE AND EUROPEAN COMPANIES IN MAKING THESE ELEMENTS OF THE INFRASTRUCTURE WORK. SIMPLY BEING FIRST WITH A TECHNOLOGICAL INNOVATION DOESN'T PROVIDE MUCH SUSTAINED BENEFIT; MANY FIRMS, NOTABLY THE JAPANESE, HAVE BEEN MUCH MORE ADEPT THAN U.S. COMPETITORS AT COST-EFFECTIVELY SPREADING AN INNOVATION RAPIDLY AND WIDELY INTO THEIR PRODUCT LINE.) THEY ARE AIDED BY EXTREMELY LOW-COST CAPITAL AND THE ABILITY TO SUSTAIN LOW PROFITS FOR MANY YEARS.

THE U.S. CONSUMER ELECTRONICS INDUSTRY OVERALL IS BEHIND ITS WORLD-CLASS COMPETITION IN JAPAN AND EUROPE. THE U.S.-BASED INDUSTRY HAS RETREATED FROM LOWER-MARGIN PRODUCTS. THE LOW PROFIT LEVELS AND NEED FOR CONTINUAL REINVESTMENT IN THE BUSINESS HAVE LED MANY U.S. HEADQUARTERED COMPANIES TO LEAVE THE TV BUSINESS. U.S.-HEADQUARTERED ELECTRONICS COMPANIES HAVE LARGELY WITHDRAWN FROM CONSUMER ELECTRONICS MARKET, AND SUCCESSFUL ELECTRONICS COMPANIES DECLINE TO ENTER, FOR THE EXPLICITLY STATED REASON THAT THE RETURN ON INVESTMENT AVAILABLE IS BELOW THE COST OF CAPITAL. AND, THE U.S. LACKS LOW-COST HIGHLY AUTOMATED COMPLEXES COMBINING MANAGEMENT, ENGINEERING, AND MANUFACTURING OF HIGH-VALUE-ADDED VIDEO PRODUCTS SUCH AS THOSE YOU FIND OVERSEAS. AND, LAUNCHING THE HDTV MARKET IN THE U.S. REQUIRES LONG TIME HORIZONS, AS LARGE INVESTMENTS MUST BE MADE IN THE 1990s, BUT PROFITS WILL NOT LIKELY BE ENJOYED FOR AT LEAST FIVE TO SEVEN YEARS AND PERHAPS NOT BEFORE THE NEXT DECADE.

AN U.S. INDUSTRY RESPONSE

THE AEA HDTV BUSINESS PLAN GROUP (COMPRISED OF 36 AEA MEMBER COMPANIES) CONTRACTED WITH THE BCG (BCG) TO IDENTIFY A STRATEGY FOR PARTICIPATION BY THE U.S. ECONOMY IN HDTV AND ITS PRODUCT SPINOFFS. THIS PLAN IS OFFERED AS A STARTING POINT FOR THE DEBATE OVER AMERICA'S INVOLVEMENT IN HDTV TECHNOLOGIES.

THE BCG FOUND THAT BECAUSE OF:

- THE SIZE OF INVESTMENT REQUIRED,
- THE ANTICIPATED MODEST RETURNS UNTIL SOME TEN YEARS OUT,
- THE TIME AND RISK NEEDED TO DEVELOP THE MARKET, AND
- THE FACT THAT JAPAN AND EUROPE ARE SO FAR AHEAD IN HDTV TECHNOLOGIES,

MOST U.S. ELECTRONICS FIRMS ARE RELUCTANT TO PARTICIPATE EITHER INDIVIDUALLY OR AS PART OF A COLLECTION OF COMPANIES WITHOUT SERIOUS FINANCIAL RISK REDUCTION. BCG REPORTED, HOWEVER, AND AEA CONCURS, THAT WITH A DECISIVE, INDUSTRY-LED, JOINT INDUSTRY/ GOVERNMENT SUPPORTED STRATEGY, THE U.S. COULD BUILD A STRONG BASE IN HDTV AND OTHER HIGH-DEFINITION PRODUCTS AND COMPONENTS.

HDTV BUSINESS PLAN

THE BCG BELIEVES THAT A U.S.-BASED HDTV INDUSTRY CAN BE ESTABLISHED, WITH WORLD-CLASS ENGINEERING/MANUFACTURING INFRASTRUCTURE FOR VIDEO PRODUCTS AND A HIGH LEVEL OF U.S.-BASED VALUE ADDED AND TECHNOLOGY CONTENT, THROUGH A SIX POINT PROGRAM. THE PROGRAM WOULD PROVIDE ONE-TIME CATCH-UP ASSISTANCE TO THE U.S. INDUSTRY TO REBUILD ITS TECHNOLOGY BASE AND INFRASTRUCTURE. IN ADDITION, IT WILL USE THE ECONOMIC VALUE OF THE TECHNOLOGY UNDERLYING THE BROADCAST STANDARD TO ENCOURAGE LOCATION OF VALUE ADDED AND TECHNOLOGY CONTENT IN THE U.S., AND TO FUND CONTINUING REINVESTMENT IN THE U.S. TECHNOLOGY BASE. WITH THESE STEPS, THE U.S. SHOULD HAVE A FULLY COMPETITIVE, BROAD-BASED VIDEO PRODUCTS INDUSTRY, COMPETING IN AN OPEN MARKET.

THE KEY LEADERSHIP ROLE IN THIS PROGRAM IS PLAYED BY AN INDUSTRY-LED BODY CALLED THE "HDTV ADVISORY BOARD" THAT COORDINATES INDUSTRY DEVELOPMENT AND ADMINISTERS ASSISTANCE PROGRAMS ON BEHALF OF THE GOVERNMENT; IT WILL NOT MANUFACTURE OR MARKET ANY PRODUCTS. ALL PRODUCT DEVELOPMENT, PRODUCTION, AND MARKETING WILL OCCUR IN PRIVATE COMPANIES THAT DECIDE, INDIVIDUALLY OR IN ALLIANCES, TO INVEST THEIR OWN FUNDS TO ENTER THE HDTV MARKET AND BECOME ELIGIBLE FOR THE ASSISTANCE PROGRAMS; THE GOVERNMENT HAS NO ROLE IN INITIATING INVESTMENTS OR DESIGNATING WHICH COMPANIES WILL PRODUCE WHICH PRODUCTS.

THE SIX POINTS OF THE PROGRAM ARE:

1. ESTABLISH AN INDUSTRY-MANAGED, GOVERNMENT-SUPPORTED BODY ("HDTV ADVISORY BOARD") TO LEAD, COORDINATE, AND MONITOR THE ACTIONS NEEDED TO BUILD AN HDTV INDUSTRY IN THE U.S. THE HDTV ADVISORY BOARD WILL OTHER COMPANIES DEVELOP HDTV-RELATED BUSINESS.

2. MAKE LOWER-COST CAPITAL AVAILABLE TO THE HDTV INDUSTRY FOR INVESTMENT IN RESEARCH, INFRASTRUCTURE DEVELOPMENT, AND BUSINESS GROWTH.

3. BUILD WORLD-CLASS INFRASTRUCTURE FOR SYSTEM AND COMPONENT ENGINEERING AND MANUFACTURING FOR HDTVs AND OTHER HIGH RESOLUTION IMAGING PRODUCTS.

4. PLUG KEY HOLES IN THE U.S. TECHNOLOGY BASE AND PURSUE BREAKTHROUGH OPPORTUNITIES.

5. SELECT AND ADMINISTER THE BROADCAST AND PROGRAM INTERCHANGE STANDARDS IN A WAY THAT FOSTERS DEVELOPMENT OF THE U.S.-BASED INDUSTRY.

6. MAKE PUMP-PRIMING INVESTMENTS TO SIMULTANEOUSLY BOOST PROGRAM AVAILABILITY AND THE CUSTOMER BASE.

HDTV IS A MAJOR MARKET AND TECHNOLOGY CHANGE THAT WILL CREATE OPENINGS FOR NEW STRATEGIES AND NEW ENTRANTS. ESTABLISHING AN HDTV BUSINESS WILL BE EXPENSIVE, HOWEVER, AND MAY REQUIRE A LONG TIME HORIZON FOR PAYOFF. JUMP-STARTING THE MARKET WILL REQUIRE CONCERTED ACTION, INVESTMENT, AND LEADERSHIP BY THE EQUIPMENT, PROGRAMMING, AND BROADCASTING INDUSTRIES AND THE INVOLVED GOVERNMENT AGENCIES, INCLUDING CONGRESS AND THE AMDINISTRATION, TO PUT ALL THE SYSTEM ELEMENTS IN PLACE SIMULTANEOUSLY.

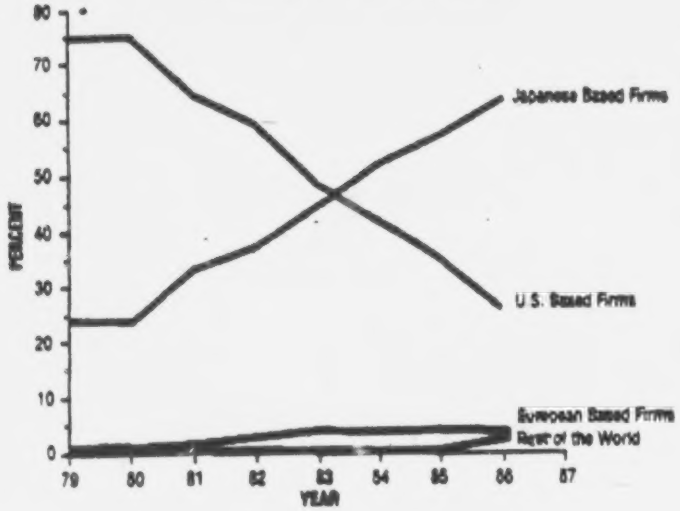
ELECTRONICS PRODUCTS

WORLDWIDE PRODUCTION

EIAJ DATA - 1988

	1984	1985	1986	1987
USA	50.4%	47.8%	41.2%	39.7%
JAPAN	21.3%	21.4%	24.9%	27.1%
W. EUROPE	23.5%	24.9%	27.6%	26.4%
OTHER	4.9%	5.9%	6.3%	6.8%

MEMORY PRODUCTS: WORLD MARKET SHARE
percentage of world shipments



WORLD SHARE OF DYNAMIC RANDOM ACCESS MEMORY PRODUCTS (DRAMS)

	1976	1980	1987*
U.S.	95.8%	55.6%	17.9%
Japan	4.2%	39.4%	73.0%
Europe	—	5.0%	2.0%
Rest of World	—	—	7.1%

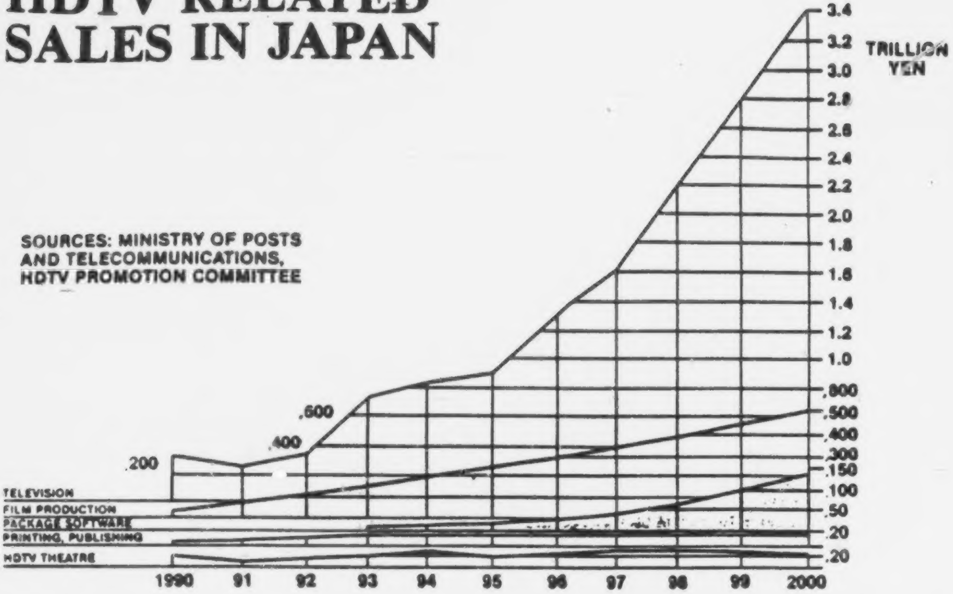
* In 1987, the value of the world market for DRAMS was $2.6 billion.

U.S. Share of Worldwide Electronics Product Markets
(1985-1987)

Industry	Percent 1984	Percent 1987	Industry	Percent 1984	Percent 1987
Silicon Wafers	85	22	Floppy Drive	35	2
ATE	75	68	Hard Drive (up to 300 MB)	73	65
Memory Test	53	36	Hard Drive (up to 40 MB)	70	60
SME	62	57			
Microlithography	47	35	Software	70	70
			OS	90	90
Semiconductor	54	41			
ASICs	60	50	COS	35	19
DRAMs	20	8	Optical Cable	75	50
MPUs (all)	63	47			
MPUs (80C88/80C86)	23	23	Instruments	52	46
Computers (all)			Photocopiers (U.S. Market)	40	36
Computers (PCs)	69	64			
Computers (Laptops)	85	63			
Displays (all)	11	8	Consumer Electronics	19	12
Flat Panel Display	25	15			

SILICON VALLEY GROUP, INC.

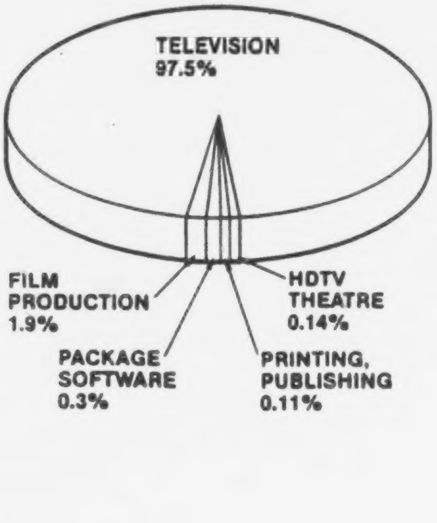
HDTV RELATED SALES IN JAPAN

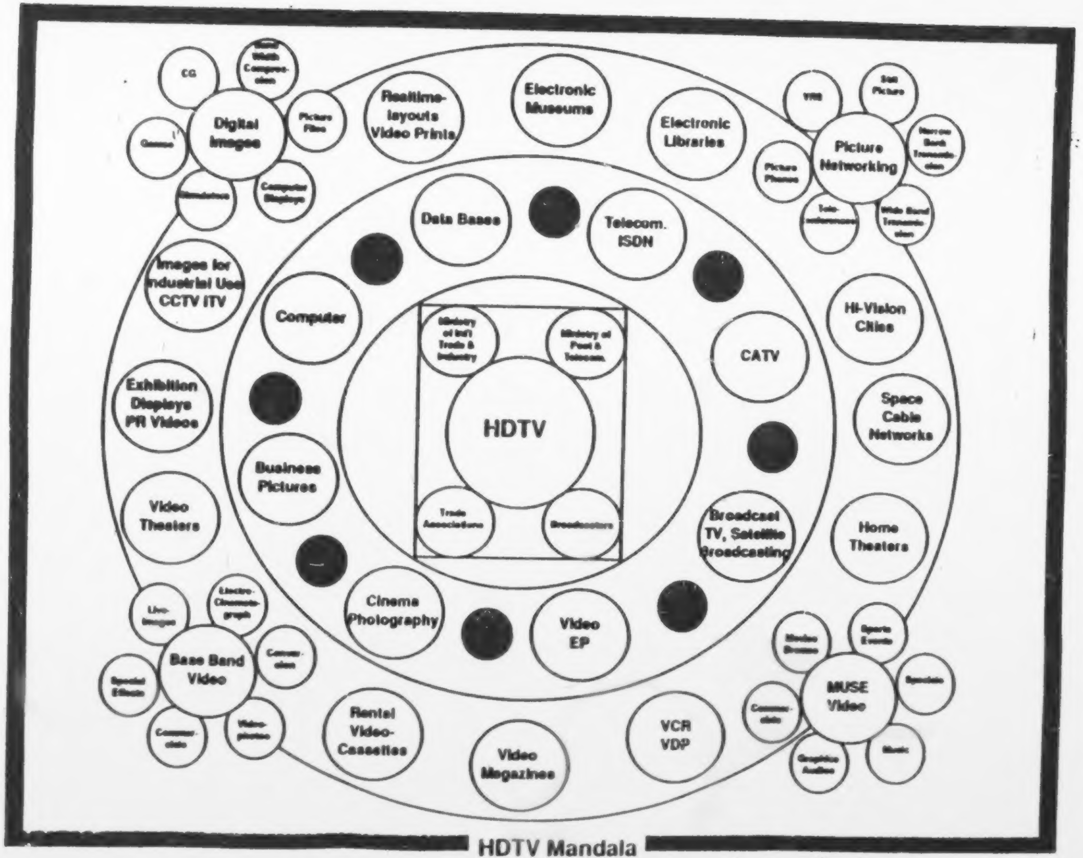


SOURCES: MINISTRY OF POSTS AND TELECOMMUNICATIONS, HDTV PROMOTION COMMITTEE

TOTAL RELATED SALES 14.5 TRILLION YEN 1990 TO 2000

At 150 YEN/DOLLAR = 100 Billion Dollars




HDTV
Ministry of Int'l Trade & Industry
Ministry of Post & Telecom.
Trade Associations
Broadcasters
Data Bases
Telecom. ISDN
CATV
Broadcast TV, Satellite Broadcasting
Video EP
Cinema Photography
Business Pictures
Computer
Realtime-layouts Video Prints
Electronic Museums
Electronic Libraries
Picture Networking
VRS
Still Picture
Narrow Band Transmission
Wide Band Transmission
Teleconference
Picture Phones
Hi-Vision Cities
Space Cable Networks
Home Theaters
MUSE Video
Studio Dramas
Sports Events
Specials
Music
Graphics Audios
Commercials
VCR VDP
Video Magazines
Rental Video-Cassettes
Base Band Video
Live Images
Electro-Cinematograph
Conversion
Video-phones
Commercials
Special Effects
Video Theaters
Exhibition Displays PR Videos
Images for Industrial Use CCTV ITV
Digital Images
CG
Band Width Compression
Picture Files
Computer Displays
Simulation
Games

HDTV Mandala

GIANT ELECTRONICS Concept

Objective: **Develop various fundamental technologies needed to realize 1-meter square [display] circuit elements**

Suggested Time / Expense Frame: 7 Years / ¥13,000,000,000

Expected Participants: **Hitachi, Sharp, NEC, Seiko Epson, Casio, Sanyo, (Fujitsu, Thomson Japan, Hoechst Japan, Japan Sheet Glass) Toppan, Dainippon Printing, Asahi Glass, Chisso, Ulvac**

Topics For Basic Technological Development:

✻ **Large-surface, high-precision glass sheet technology (high uniformity, high heat resistance, low-alkali, low deformity)**

✻ **Large-surface, high-precision thin-film technology (high-function semiconductor films, high-function circuitry film)**

✻ **Large-surface, high-precision patterning technology (high-precision mask, exposure and printing technologies)**

✻ **High-function liquid crystal materials technology (low viscosity, high resistance, optimum sharpness)**

✻ **Large-surface high-precision assembly technolgy (ultra-large thin layer lamination, implantation, shielding)**

Potential Products Using Technology :

Book-Size Computers

Ultra-High **Density** Optical Disks

Large-Surface, Thin Light Sources

Optical Publishing Technology

Fast Response Liquid Crystals

Production Of Electronic Components Via "Printing"

"Chip On Glass" Circuitry

Ultra-Thin Insulating Materials

AEA Japan Office

A CRITIQUE OF THE CONGRESSIONAL BUDGET OFFICE'S ANALYSIS OF THE FORECASTS OF THE ECONOMIC IMPACT OF HIGH DEFINITION TELEVISION

by Dr. Robert Cohen,
Consultant to the American Electronics Association

I. Major Shortcomings of the Report

A. The Narrow Definition of HDTV

The Congressional Budget Office (CBO) report, "The Scope of the High-Definition Television Market and Its Implications for Competititveness," views HDTV as an improvement in television. But the CBO report failed to consider the impact of high definition systems (HDS) on the broader electronics industry. These systems will result in video images integrated into computing and better video controls for manufacturing and service firms. In recognition of these significant impacts, Japanese HDTV initiatives have explicitly emphasized computer-aided design and manufacturing (CAD/CAM), medical applications, printing advances, and enhanced control systems.

The CBO report interprets the HDTV market studies by the American Electronics Association (AEA), the Electronics Industry Association (EIA), and the U.S. Department of Commerce's National Telecommunications and Information Administration as evaluations of a new type of television. This is the narrowest possible interpretation of these analyses.

The AEA study stressed the critical role of linkages. Although CBO missed this point and failed to undertake the serious impact analysis that was needed, few in the electronics industry would dismiss the notion that a vibrant HDTV industry would create dramatic changes in a wide swath of industries.

B. Comparing HDTV's Demand for Semiconductors to the World Market for Semiconductors

The CBO report concludes that HDTV is unlikely to be significant and is more likely to have little impact on the U.S. electronics industry. This reasoning is based upon a comparison between the demand for semiconductors by HDTV's produced in the U.S. in 2010 and the world market for semiconductors in 2010.

Since the demand for semiconductors in HDTVs in 2010 is less than $1 billion and the world market is $300 billion, the CBO report (see Figure 4) assumes that HDTV would have no chance to have a major impact on the U.S. electronics industry. However, this reasoning is flawed since it fails to include any impacts of a successful HDTV or high definition displays initiative on a wide range of industries that would be affected.

By resting its case on such flawed logic, the CBO does itself a disservice. It could have reviewed any of the recent reports by the Japanese ministries involved in promoting HDTV to see how clearly they recognize HDTV as a vehicle for improving competitiveness in the communications, computer, and software industries. By failing to undertake a more sophisticated analysis of the linkages in the electronics industry, the CBO report limits its analysis to the narrow, and implausible, changes that may occur if HDTV is only a very limited consumer television product. Many economists who work with input/output tables of the national economy would argue that a more sophisticated method to evaluate the impact of a critical new technology should have been used.

The CBO viewpoint is a direct result of being unwilling to consider the broader applications of high definition systems. In contrast to the CBO report, many experts believe that high definition systems (HDS) will affect a wide range of industries. One vision of the future home entertainment center is a single system, with a high resolution display, that serves as a HDTV, home computer, and home communications and business link Such a system would permit home banking, home shopping, educational use of data sources, time sharing, and rapid data and video communications. Corporations are already using high definition systems for computer-aided design and manufacturing. A wide range of manufacturing industries is experimenting with ways to apply advanced displays and high-speed communications to their operations.

Thus, the conclusions of the CBO report fly in the face of recent moves by Japanese and European firms that are betting their future on HDTV, with considerable government support.

Having just returned from a trip to Japan with the National Science Foundation Japan Technology Evaluation Committee on HDTV, I can attest to the fact that Japan's largest corporations are viewing HDTV as a real technology driver. As I shall discuss below, HDTV has already provided NHK an opportunity to build a collaborative group of semiconductor firms that has greatly advanced Japanese technology in ASICs, application specific semiconductors, for HDTV. Such advances, promoted by the move to HDTV, clearly demonstrate how high definition systems will serve as a technology driver. In addition, Japanese corporations are using HDTV as a technology driver in CAD/CAM and workstations.

As the participants in the NSF panel held in our hands the latest MUSE system compression board with 50 custom ASICs, we were confronted with evidence proving that crucial advances in semiconductor technology would be directly linked to Japan's HDTV efforts. This board, together with another similar to it, replaced 50 boards. We were told that 3 or 4 chips would soon replace the board that we saw.

There is ample evidence from the NSF panel visit to Japan that a wide range of commercial applications were being explored to promote advanced TV. In addition, the fact that the "bus" or communications backbone of advanced TV handles such large amounts of data so rapidly, opens up enormous opportunities to break ground in video memory and optical memory. These fields for technology advances may provide the Japanese with a vast technology lead that could threaten U.S. security. It is these losses of key technology competence that the recent IEEE workshops have underscored and that the NSF panel on HDTV is likely to address.

C. The Key Shortcomings of the Report

The main conclusions of the Congressional Budget Office (CBO) study are:

> 1) "Even the optimistic forecasts of the potential size of the HDTV market are small relative to the other markets in the electronics sector. Thus, it is unlikely that HDTV will play a pivotal role in the competitiveness and technology development of the sector as a whole." (CBO, p. vi)

2) The development of HDTV will not create a valid driving technology that will have much influence on other parts of the larger electronics industry since "the most optimistic forecasts of the HDTV market are small relative to the other markets in the electronics sector. Thus, it is unlikely that HDTV will by itself revitalize the U.S. electronics sector. " (CBO, p. 28) An implied conclusion is that it is not important for the U.S. government to be involved in helping the electronics industry move into HDTV, particularly if it might prove to be a mass market product with low profit margins.

The CBO report also misunderstands the true dynamics of the electronics industry. The most successful challenges by foreign competitors to U.S. electronics firms have been based upon strengths in mass production that have been used to drive down costs. Most U.S. firms have given up on learning how to control mass production and how to compete in mass produced, or "commodity" electronics, such as television and semiconductors. In some cases, they have not been able to raise the capital to undertake the development of mass-market products or low-profit intermediate products. At times this has been due to the short-term focus of investors and Wall Street analysts.

However, an effort to focus on more profitable technologies and the control of intellectual property, cited in the CBO report as the most logical way to strengthen our electronics sector, doesn't cut the mustard in the world of electronics. This concentration on moving to ever higher ends of markets has led most U.S. manufacturers to forget about the great potential sales of mass-produced consumer goods. These goods --the VCRs of today and the HDTVs of the late 1990s and early years of the next century -- require the mastery of mass-produced components in order to compete in world markets.

By ceding what is believed to be the lower end of markets, U.S. firms have, with some exceptions, overlooked the fact that mass production of technology products and the mastery of processing techniques often leads to critical economic benefits in the marketplace. Thus, the increasing inability of U.S. firms to produce advanced semiconductors may not result in an immediate decline of our industry, but can lead to a long, insidious downward movement. It may also result in situations where our more competitive firms in computers and electronics tend to underestimate the true adjustments that they need to make to remain competitive, giving more weight to short-term pressures than long-term investments that are needed to respond to new competitive thrusts by their competitors.

To summarize, there are seven key shortcomings of the CBO Report:

1) The study fails to analyze how efforts in the area of advanced TV can act as a driver to technology development. Initiatives for HDTV, such as the Japanese have undertaken, are providing a vehicle for major advances in semiconductor, digital processing, and display technology. These initiatives recognize that the rapid "bus" in advanced TVs and the potential to develop entirely new displays -- with up to 10,000 lines of resolution, as the Japanese are now considering-- can set off a series of chain reactions that energize economic growth.

2) The study fails to use serious economic techniques to evaluate the major impacts that are assumed by experts who developed the AEA, EIA and Darby reports. The only way that the move to advanced TV could create large economic effects is by creating "chain reactions" that would ripple through the economy in a way that the development of the computer has. Today, 40 cents of every U.S. dollar spent on new investment is flowing into information-related (computer, communications and TV industries), up from just 14 cents in 1952.

   The only proper way to see if the huge impacts of the AEA, EIA and Darby reports may come to pass is to use an evaluation of the "chain reactions" that the move to advanced TV, entirely new architectures for TV, and greatly improved memory and processing capabilities for the telecommunications industry would bring about in the economy.

   Many of these chains would have to be broken if dramatic losses in semiconductor production were to occur in the U.S. Losses of exactly this magnitude have been of great concern to the leading scientific bodies in the nation, such as the IEEE, which recently concluded that the U.S. was facing a future crisis in semiconductors that could threaten the development of a broad spectrum of industries in the electronics sector.

3) The CBO Study avoids mention of the key steps being taken by Japan and the European Community to develop HDTV, although the National Science Foundation has appointed a committee to study Japanese efforts in HDTV, which returned from Japan while this study was being done. This oversight means that the Congress is given a biased view of how significant HDTV developments are likely to be. It is as though the President had access to significant new intelligence information, but failed to bring it to the attention of the relevant Senate committees.

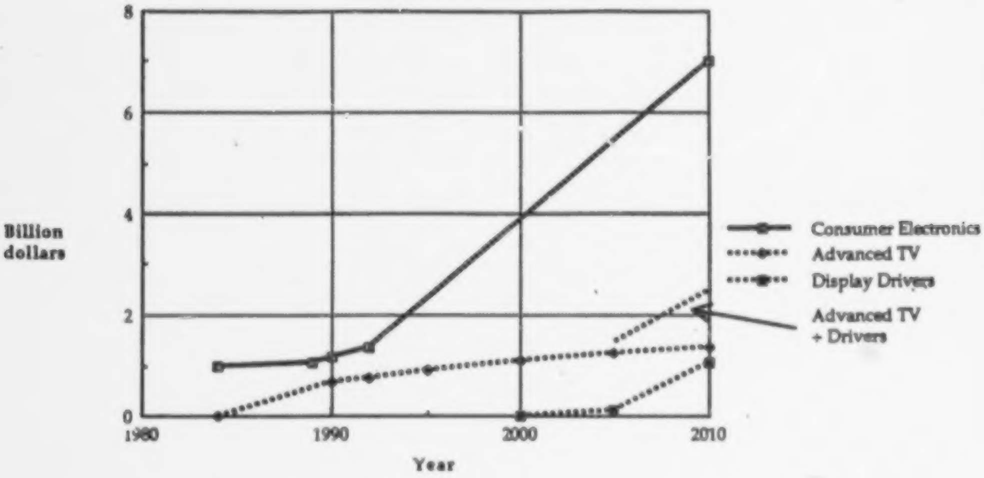
4) The CBO Study concludes that since the use of semiconductors in U.S. HDTVs would not be a sizable part of world semiconductor sales in the year 2010, HDTV will have few impacts on the electronics industry, in spite of the fact that evidence shows that advanced TV consumption of semiconductors will be more than 50 percent of chip consumption by the consumer electronics market in the U.S. early in the 1990s. (See Table, "Consumption of Chipsets, 1984-2010").

5) The CBO study fails to consider some of the recent proposals for tying advanced TV development to open architectures for computing and communications, thus leaving out of consideration any ties to these industries.

6) The CBO study also fails to see how the leverage of the semiconductor industry is key to the most critical industries in our own electronics sector, communications, computers, defense, and optical equipment.

7) The study also attempts to evaluate advanced TV as a "technology driver" solely in terms of sales and there are few experts in the technical areas of advanced TV who are cited in the introduction in the study. Thus, emerging firms in advanced TV, such as Planar Systems and Fibermedia, were never consulted. Nor were experts at firms, such as IBM, Intel, AT&T, DEC, and other corporations, who might have allowed for some "reality testing" about what the move to advanced information displays and the information systems markets of the future will mean to the U.S. economy. None of the firms that were participants in the competition for DARPA funds appears to have been consulted. The names of these firms have appeared in every major electronics paper.

Consumption of Chipsets, 1984-2010



Semiconductor value in TV
as a percent of consumer electronics: 58% 37% 29% 25% 30%

II. Responding to the CBO Report's Conclusions

The conclusions of the CBO draft are drawn from an analysis of three sets of projections of the market for HDTV done by the American Electronics Association (AEA), the Electronics Industry Association (EIA), and the U.S. National Telecommunications and Information Administration of the Department of Commerce. While the figures in these studies differ in their opinions about the speed at which HDTV will become a commercial success, they all foresee it as a major new part of consumer electronics. In the AEA study, the rate of commercial penetration of HDTV is more conservative since it is based on color television's penetration rate rather than the more rapid success of VCRs in the EIA report. But the CBO draft still considers both of these projections to be "optimistic" (p. vi).

The response presented here will begin by focusing on the failure of the CBO study to ascertain the true dimensions of the international electronics industry by focusing on the three reports and not the dynamics of the industry. In some cases these dynamics were not spelled out by the expert groups developing the projections, but this expert knowledge was subsumed in the estimates of impacts on related electronics industries that were developed for the AEA report. The response will then examine evidence for HDTV acting as an important driver in the advancement of electronics technology. Third, the response will focus on some of the specific issues concerning the estimates in some of the studies.

A. HDTV is Part of a Vast Economic Transformation: The Move to an Information Economy

HDTV is the most prominent representation of a huge transformation of the world's leading economies. In a recent study by Japan's Ministry of International Trade and Industry (MITI) it was estimated that by the year 2000, one-third of Japan's GNP would be come from electronics and information industries, triple the percent of 1984. Behind this is a dramatic effort by Japanese firms and government agencies to build a new "Information Economy" that will outclass any in the world.

What evidence is there that this transformation will occur? While much of the material to document the change is anecdotal, it is very germane to the evaluation of the three reports reviewed by the CBO study. Many of the figures in these reports implicitly recognize some of the problems inherent in outcomes where U.S. electronics firms fail to dent the Japanese armor. The industry experts who assembled the projections, although they differ on specifics, see the vast shift to electronics and recognize that there are certain key elements that are needed in a nation's economic base if its firms are to be world-class players in electronics.

One illustration of how this transformation has already begun to affect U.S. electronics firms is the recent sizable increase in semiconductor consumption by Japan. As shown in Table 1, between 1984 and 1989, Japan is expected to more than double its consumption of semiconductors, with the computer and communications industries consuming over three times their earlier level and the consumer electronics sector nearly doubling its consumption. The U.S. figures show much lower rates of growth. If the consumer market in Japan is the driver of its mass-market strength, it is now expected to be nearly three times the size of the U.S. military's consumption of "chips," with the military purchases usually seen as the main technology driver in U.S. industry.

At the same time there is also concern about the growing weakness of many U.S. firms in the DRAM business. For instance, IBM has emphasized its own internal production of DRAMs not only because it assures a source of supply -- avoiding disruptions and buffering IBM from any price rises -- but also because it provides IBM with the ability to master critical production processes key to obtaining high yields in semiconductors. Indeed, according to Michael Attardo, president of IBM's General Technology Division, DRAMs are a technology "driver" since the process used to make them leads that for other types of chips by eighteen to 24 months. (Louise Kehoe, "The hidden giant shares some of its secrets," Financial Times, June 14, 1989, p. 37.)

By weakening their base in DRAMs and losing out in the race to develop commercial HDTV, the U.S. electronics industry could be considerably weakened relative to its competitors in Japan. The logic followed in the CBO study fails to consider the outcomes that may be reached if nearly all of the large Japanese and European firms participate in the development of HDTV and HDTV-related products. These firms envision HDTV at the very center of a tremendous transformation of the world economy.

TABLE 1

SEMICONDUCTOR CONSUMPTION IN JAPAN AND THE U.S.
1984 AND 1989
(IN BILLIONS OF DOLLARS)

JAPAN

	1984	1989
COMPUTERS	3.15	9.62
TELECOMMUNICATIONS	1.03	3.04
CONSUMER ELECTRONICS	3.39	5.78
ALL CATEGORIES	8.77	21.3

UNITED STATES/NORTH AMERICA

COMPUTERS	6.02	7.99
TELECOMMUNICATIONS	2.03	2.46
CONSUMER ELECTRONICS	0.97	1.05
MILITARY	1.27	1.97
ALL CATEGORIES	13.14	17.43

SOURCE: DATAQUEST

B. Foreign Corporations and Governments Recognize the Vast Commercial Potential of HDTV

1. Corporate Initiatives

There is a growing body of evidence that suggests that HDTV is becoming extremely important in the plans of major electronics firms. Japan's largest electronics firms have begun national sales campaigns to market the first HDTVs, now that NHK, the national broadcasting system, is providing one hour a day of commercial programming. Sharp has designated HDTV development as an "urgent development project" and given responsibility for its efforts to a group of leading experts to jump-start its participation. NEC Home electronics is staking "the very existence of its home electronics appliances division" on its HDTV project. It has emphasized the new software for HDTV. Mitsubishi has strengthened its sales force for HDTV-related products and will concentrate on digital VCRs and display monitors. By the fall, it will be selling 200- to 300-inch projection displays. (Yasuhiro Suzuki, "High-definition TV leaves the lab as part of national sales campaign, " Japan Economic Journal, July 8, 1989, p. 13.)

Major U.S. firms have been some of the first users of HDTV. Ford's Dearborn, Michigan, design facility is using a Sony system for CAD/CAM, developing designs on a 38-inch Sony HDTV monitor and then projecting them through a 300-inch system. This system has now been purchased by Ford for its two European design centers. Ford has found HDTV's wide screen format to be especially well suited to the design of cars, engines and other auto subsystems. Through such sales to industrial users, Sony is able to build the economies of scale that are needed to move to lower prices that will be needed before consumers will buy HDTVs.

2. Government Support

Japan's Ministry of International Trade and Industry has certainly recognized the potential for HDTV and has funded a new initiative that focuses on large flat-screen displays. These will do away with the TV tubes that become very costly once they are over 40-inches in diameter. The new MITI Giant Electronics or Giant Technology Project will receive nearly $100 million that will be matched by almost $300 million of company development funds. Nothing on this scale has been announced by U.S. companies. In addition, the European Community recently announced a $4 billion JESSI (Joint European Silicon Structures

Initiative) that will complement many of the ongoing efforts by companies in Europe to develop HDTV.

C. HDTV Has the Potential to Alter the Dynamics of the Electronics Industry

The key shortcoming of the CBO report is its assumption that HDTV will not be significant since its impact on the world semiconductor industry will be infinitesimal. Figure 4 of the CBO report compares the consumption of semiconductors in HDTVs built in the U.S. in the year 2010 -- estimated at $682 million based on figures in the AEA study -- with total world sales of semiconductors in 2010, which are estimated to be $303 billion. Since the consumption of chips in HDTV is so small, the CBO report concludes that it is implausible for it to have much of an impact on the semiconductor industry, especially to create the significant differences in the shares of U.S. manufacturers in the world semiconductor market.

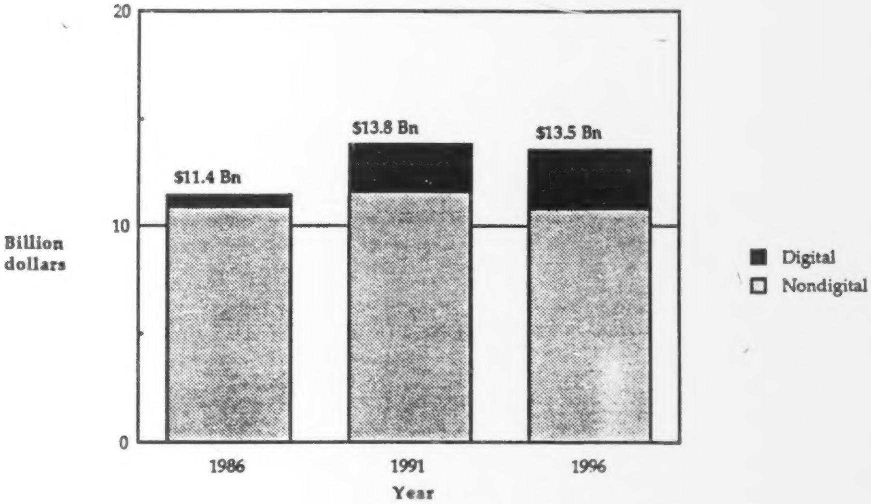
Any analysis of the economic impact of HDTV needs to include an assessment of the evolutionary steps on the way to the development of HDTV. However, the CBO analysis fails to incorporate any consideration of the semiconductor demand that is likely to come from the development of IDTV, improved definition TV, and from enhanced definition TV, EDTV.

Data that are available from BIS Macintosh, the British electronics consulting firm that is owned by NYNEX, show that the use of chips by both IDTV and EDTV will be significant, raising the share of digital chips in TVs from 4.5 percent of the factory cost to nearly 20 percent over the ten years between 1986 and 1996.

The chips that are expected to be used in advanced TV (both IDTV and EDTV) will require more than half of the chips that are expected to be consumed by the U.S. consumer electronics industry. This suggests that an initiative in HDTV or high definition systems would do much to restore U.S. strength in electronics.

Consequently, the comparison made by the CBO report between the consumption of chips in U.S.-made HDTVs and the world market for chips is disingenuous. It obfuscates the real argument made by many experts who participated in the three studies being

Use of Digital Chips in U.S. and European TVs, 1986, 1991, and 1996



Percent digital: 4.5% 16.1% 19.9%

Source: BIS Mackintosh

evaluated, namely, that strengthening the U.S. HDTV industry would provide a new dynamics to significant parts of the electronics sector by invigorating those parts of the industry that are driven primarily by market forces.

Since the consumer electronics sector is the main part of the electronics industry that would be affected by initiatives in HDTV, a fairer comparison would be to judge how substantial the consumption of semiconductors for HDTV would be in 2010 compared to the consumption of semiconductors in the U.S. consumer electronics industry in 2010. Using estimates of the total U.S. market for semiconductors from the AEA report to project such consumption from the Dataquest figures in Table 2, show that the $682 million consumption of chips in 2010 would be nearly 10 percent of the total demand for semiconductors by consumer electronics firms. Indeed, including the figure for chip demand by 12 million EDTV sets that the AEA study estimates would be sold in this year would be likely to nearly double the demand for chips, making it reasonable to argue that initiatives to invigorate the U.S. TV industry would be likely to account for approximately 20 percent of the demand for semiconductors in 2010.

These initiatives could have a large impact on semiconductor manufacturing in the U.S., especially upon the environment created to increase incentives for firms to expand their mastery over mass-production processes. Consequently, it is plausible to argue, as the experts who developed the AEA study have, that there would be dramatic declines in the world market shares of the U.S. semiconductor industry if key new product markets, that would spur critical improvements process technology and controls, do not become an integral part of the U.S. electronics industry. The loss to the U.S. economy would be that much greater if the convergence that is already taking place between computers and telecommunications broadens to encompass consumer electronics, with a greater part of competitive outcomes in the electronics industry decided more by the ability to mass produce technology-based products than by which firms can offer more sophisticated technologies.

Another problem with the CBO study is its misinterpretation of the evolutionary approach to HDTV that is taken by the AEA report. The CBO study views EDTV, the first wide-screen TV with substantial amounts of memory for image capturing and enhancement, as a type of TV that would compete

TABLE 2

ESTIMATED SEMICONDUCTOR CONSUMPTION IN JAPAN AND THE U.S. 1992 AND 2010 (IN BILLIONS OF 1988 DOLLARS)

JAPAN	1992	2010
COMPUTERS	14.5	73.
TELE-COMMUNICATIONS	4.6	23.
CONSUMER ELECTRONICS	7.0	35.
ALL CATEGORIES	30.5	150.
UNITED STATES		
COMPUTERS	12.0	60.
TELE-COMMUNICATIONS	3.3	16.5
CONSUMER ELECTRONICS	1.36	7.0
MILITARY	2.45	12.5
ALL CATEGORIES	24.99	125.

SOURCE: DATAQUEST FOR 1992 AND AUTHOR'S FIGURES BASED ON AEA STUDY ESTIMATES FOR 2010.

with HDTV. But the AEA report argues that EDTV would be part of a natural progression to HDTV, starting with IDTV and EDTV, with consumers shifting to HDTV as prices come down and broadcasting in HDTV becomes more widespread. The CBO study concludes that EDTV would remain a strong competitor to HDTV,rather than an evolutionary stage in the movement to HDTV. Based on this opinion it foresees a situation where EDTV and HDTV would be like the Beta vs. VHS systems that consumers had to choose between in the mid 1980s. However, most experts would view the development of EDTV as part of an evolution in TV, although the EIA report failed to keep the distinctions between EDTV and HDTV clear.

As a consequence of this, the CBO study does not consider the electronics needed for EDTV in its estimates of impacts of HDTV on the semiconductor industry. This is a significant oversight, since it results in an underestimation of the consumption of semiconductors by the TV industry at specific points in time.

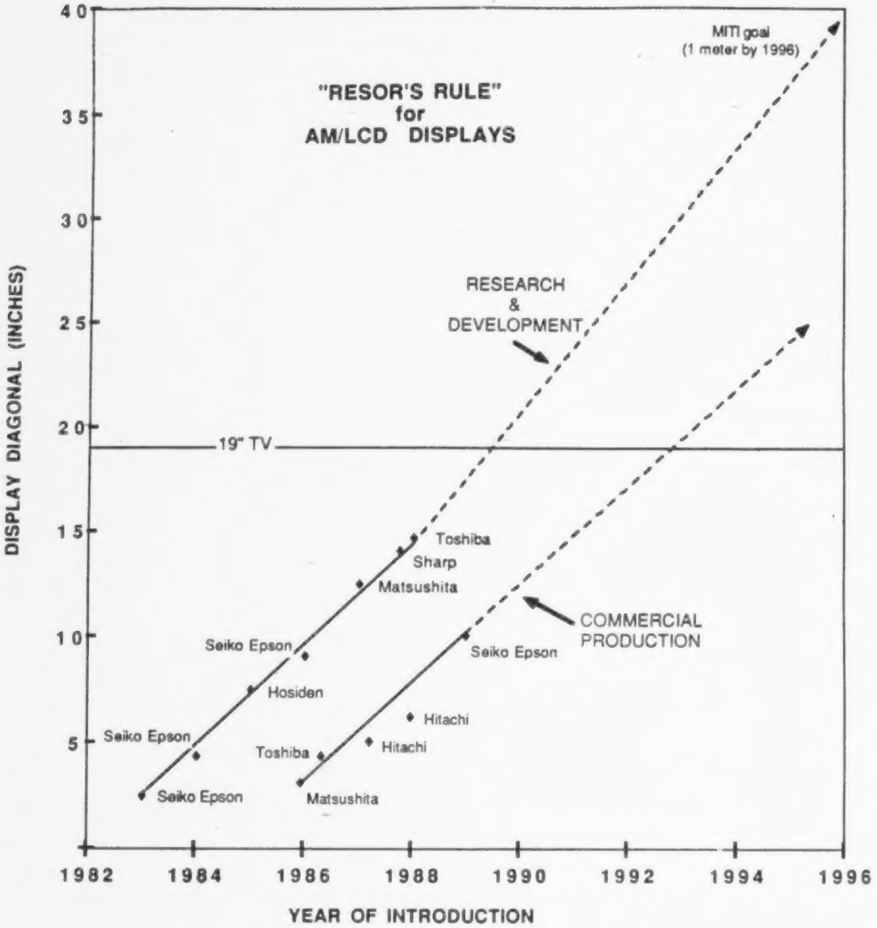
III. Reasons for Viewing HDTV as a Technology Driver for the Electronics Industry

A. The Commercial Introduction of Flat Panel Displays

The commercial introduction of flat panel displays is likely to prove a considerable benefit to the success of HDTV. In addition, though this commercial development is not considered in the CBO study, it is likely to result in substantial price reductions and easier and earlier consumer acceptance of HDTV.

The development of flat displays likely to be a technology driver since it will require the development of key new skills in fabrication of very large semiconductor arrays on glass, a technology that is only now in its infancy. While color flat panel displays will soon be included in portable computers, the real commercial market for such displays will be in large TV screens, with over 40 inch-diagonal displays.

One indication of how rapidly this field is developing is provided in Figure 1, which depicts "Resor's Rule" for Active Matrix Liquid Crystal Displays. This figure shows that R & D to create the 1 meter display by 1996 -- the goal of MITI's Giant Electronics Project that was mentioned early -- is on schedule. Having such a capability in Japan will not only provide far more



- Display size, as measured by the diagonal inch, is increasing at the rate of three inches (75mm) per year.
- Commercial introduction follows R&D production by approximately three years.

January, 1989

MRS
Technology Inc.

acceptable screens for TVs, but also offer opportunities to use "chip on glass" technology in other devices. In other words, fax machines and xerox machines could be miniaturized since their electronics could be placed on the glass scanner they contain.

Flat panels are especially important to industry and the military. According to estimates that have been developed by Joseph Castellano of Stanford Resources, Inc., liquid crystal displays will be nearly as numerous as traditional cathode ray tubes in the worldwide market for displays in military products by 1995. They will also far outnumber traditional CRTs among displays used in industrial products. (See Tables 3 and 4)

Since the displays that will be developed for HDTV will be at the leading edge of this market, they provide a real opportunity for U.S. firms to participate in a market that will have tremendous opportunities for expansion. The interest of the military in such displays is likely to remain strong, but it would greatly benefit the U.S. electronics industry if firms such as Ovonic Imaging Systems of Troy, Michigan, and Planar Inc., of Beaverton, Oregon, which are now manufacturing displays primarily for military use, found greater incentives for moving into the consumer display market.

By mastering the process technology needed to produce large numbers of flat panel displays, U.S. corporations would also be more likely to exploit the commercial potential of "chip on glass" technology. In doing this, they would improve the chances that a larger domestic market for high definition systems would be created. In addition, there would be a greater likelihood that U.S. firms would create a base for successful mass production of consumer and industrial products that would be based on the use of advanced displays.

B. The Development of Advanced Technology Chips and Decoding Devices

Another way in which HDTV may serve as a technology driver is in the development of advanced chips for memory and digital signal processing. In Japan, a consortium of NHK and the leading electronics firms recently developed a new decoding chip set for the MUSE HDTV system.

The VLSI chips developed for the MUSE decoder, recently unveiled by NHK, the Japanese Broadcasting System, was the result of a cooperative effort by Toshiba, NEC, Sony, Hitachi, Sharp and MEI. It required 26 different ASIC chip

TABLE 3
WORLDWIDE MARKET FOR DISPLAYS IN MILITARY PRODUCTS

Thousands of Units

DISPLAY TECHNOLOGY	1986	1989	1992	1995	CAGR
CRT	37	51	55	53	4.07%
LED	3	3	3	3	0.00%
PDP	2	4	3	3	4.61%
EL	1	4	5	6	22.03%
VFD	0	0	0	0	---
LCD	2	11	22	45	41.33%
TOTAL	45	73	88	110	10.44%

TABLE 4
WORLDWIDE MARKET FOR DISPLAYS IN INDUSTRIAL PRODUCTS

Thousands of Units

DISPLAY TECHNOLOGY	1986	1989	1992	1995	CAGR
CRT	1,738	2,302	3,045	4,056	9.87%
LED	6,149	6,441	6,753	7,177	1.73%
PDP	903	988	980	936	0.40%
EL	12	63	304	652	55.88%
VFD	3,534	4,271	5,194	6,152	6.35%
LCD	10,826	13,907	16,824	20,096	7.11%
TOTAL	23,162	27,972	33,100	39,069	5.98%

Copyright 1988 Stanford Resources, Inc.

designs, resulting in a complete decoder that had 96 chips, about half ASICs and half catalog chips. This reduced the size of the decoder from 2000 chips on 50 boards using conventional technology to just 2 PCBS. The result is expected to reduce the weight of a smaller HDTV receiver from 50 kilograms to 1.5 kilograms.

By promoting such advances in semiconductor technology, the development of HDTV clearly serves as a technology driver. Indeed, by taking the lead in the commercial use of such devices, the Japanese corporations that are the earliest participants in the HDTV industry could gain significant advantages over their rivals in other nations.

C. The Early Use of HDTV in CAD/CAM Design Support Systems

Another way that HDTV will act as a technology driver is by providing capabilities for large firms to enhance their CAD/CAM operations. Hitachi's Multiscan HD Projection System is being advertised as enabling design groups to make "the most complex two- and three-dimensional entities ...[visible] in their entirety --even at actual size....surface modeling techniques can replace mockups." They also permit firms to display workstation output in real-time. Shima Seiki, a Japanese producer of knitting systems, has used the Sony HDTV system to develop a computer graphics workstation that enables users to perform creative retouching on designs, which may also have applications to CAD/CAM.

Once manufacturers can use HDTV CAD/CAM devices, as Ford has done, they are likely to develop additional services they would like to have with HDTV workstations. This type of technology driver, advancing the development of "cutting edge" engineering in leading U.S. firms, could have a very positive impact on the development of innovative services that are likely to improve the competitive position of individual U.S. firms.

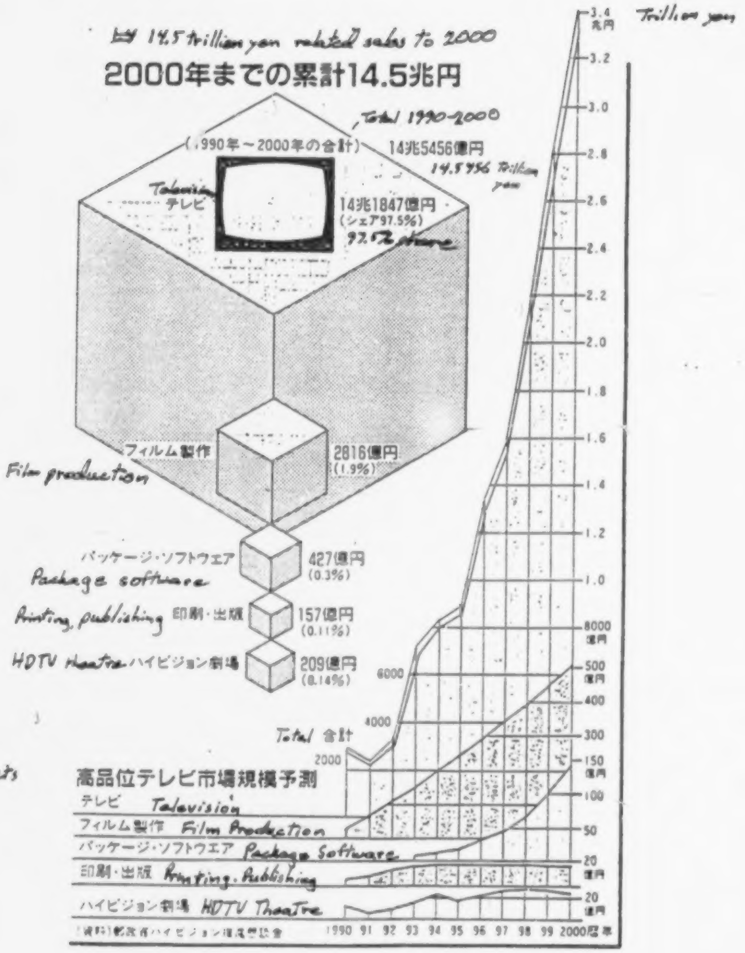
IV. Additional Data on the Growth of HDTV

The CBO study has not taken into account recent estimates of the growth of the industry that have been released by Japanese agencies. The Ministry of Posts and Telecommunications recently provided an estimate that nearly $ 20 billion worth of HDTV sets would be sold by the year 2000 (see Figure 2). This figure is significant, since it is far more optimistic than any of the U.S. reports reviewed in the CBO study. The AEA report estimates that the Japanese market in 2000 will only have sales of $ 2.4 billion worth of HDTV sets.

14.5

Trillion ¥

Projected HDTV markets



（資料）郵政省ハイビジョン推進協議会

Source: Ministry of Posts and Telecommunications, HDTV promotion committee

STATEMENT OF

PETER F. McCLOSKEY

PRESIDENT

ELECTRONIC INDUSTRIES ASSOCIATION

BEFORE THE

SENATE GOVERNMENTAL AFFAIRS COMMITTEE

UNITED STATES SENATE

August 1, 1989

*****

Good morning. My name is Peter McCloskey. I am the President of the Electronic Industries Association, the leading trade organization representing the electronics industries, protecting its interests and aiding in the shaping of its future for over 64 years. EIA's 1,200 members represent every facet of the electronics industry, from defense to telecommunications to components to end products. EIA's members all have U.S. facilities and 94 percent are U.S.-owned companies. EIA's members' sales account for over 85 percent of the dollar volume of electronics manufactured in the United States.

For our industry, 1988 represented a very good year. U.S. factory sales of electronics increased 11 percent to a record breaking $248 billion. Electronics exports were up 38.6 percent in 1988, compared to an 18.6 percent rise in imports, resulting in a 27 percent drop in the electronics trade deficit.

EIA LEADERSHIP IN ELECTRONICS INDUSTRY STANDARDS

The EIA is known worldwide, not just as the voice of the U.S. electronics industry, but as a worldwide standards-setting organization. The EIA helps set voluntary standards for many products. For example, computer and data communications interfaces among products of various manufacturers are possible because of EIA standards such as EIA 232-D and EIA 488 data communications standards. And perhaps most relevant here, is the critical role EIA played in the creation of the original NTSC standard in the 1930's and the color television standard in the 1950's. These and other standards reflect EIA's philosophy that while standardization does not create an industry, it allows it to develop. Standards minimize consumer confusion, ensure compatibility and expedite consumer acceptance of a product.

Virtually every standard also creates U.S. jobs. An excellent example of this fact is the home automation standard for home control systems that EIA is now shepherding. This emerging standard is gaining world recognition and it has already created opportunities for scores of large, small and new U.S. electronics companies.

EIA AND ITS ATV COMMITTEE

In 1987, EIA formed a committee to consider public policy and technical issues associated with advanced television. The EIA/ATV Committee includes representatives across the broad spectrum of the electronics industry (membership list attached). EIA's ATV Committee includes developers, manufacturers, sellers and installers of studio, broadcast, transmission and consumer equipment. Their interests are far broader that just the receiver industry and encompass the entire television/entertainment market with assets valued in excess of $300 billion. Participating in the EIA/ATV Committee are EIA members, including members of the EIA's affiliate -- the Telecommunications Industry Association (TIA), as well as non-EIA members.

The Electronic Industries Association and its member companies have been participating in several activities that promise to bring HDTV technology to American consumers.

EIA staff and its members are participating in many of the FCC Advisory Group's Committees and Working Groups. An EIA Engineering VP is Vice-Chair of the ATS Testing and Evaluation Specifications Working Party, and several members are serving on other committees. EIA has also provided comments and input on a number of technical and policy issues being reviewed by the FCC in regards to HDTV.

In efforts to expedite the setting of a timely transmission standard, EIA is also working closely with the Advanced Television Test Center (ATTC) in its role of systems testing.

Finally, EIA is fully supportive of the funding that DARPA is providing to encourage vital research on flat panel displays and other related technologies. Such technology promises to provide benefit to several industries and not solely the consumer HDTV industry.

Beyond HDTV, the EIA has been, is, and will continue to be active in support of overall competitiveness enhancing measures. For example, we would encourage the U.S. Congress to amend antitrust law to allow for joint production ventures, as the opportunity to cooperate in sharing financial risk will provide U.S. industry with the flexibility it needs to meet world competition.

Also, earlier this year, I testified before the House Ways and Means Committee on the need to permanently extend key competitiveness provisions currently in the tax code. As you know, Mr. Chairman, the twin issues of the R&D tax credit and the Section 861-8 R&D allocation regulations, are very important to the U.S. electronics industry and have been high priority issues for EIA throughout the 1980s. We have worked with your colleagues on the Finance Committee to ensure the permanent extension of these provisions and believe they will significantly enhance the ability of our industry to compete in the global marketplace of the next century.

THE EIA REPORT

In November of 1988, EIA launched the HDTV Information Center as an authoritative, one-stop information resource that can respond to the many HDTV queries posed by the media, Congress and the general public. Since its inception, the HDTV Information Center has handled over 3,000 inquiries. The cornerstone activity that launched the Information Center was the release of the Robert R. Nathan Associates (RRNA) study on "High Definition TV's Potential Economic Impact on Television Manufacturing in the United States."

The "EIA/Nathan Report" was the product of a full year of consultation with set manufacturers. This Report had the advantage of receiving input from those companies that are manufacturing televisions sets today. The companies that contributed their experience and knowledge to this Report are the actual participants in a highly competitive consumer electronics industry that lives with the reality of miniscule profit margins. These manufacturers are familiar with TV products development and marketing.

A. Nathan Study Assumptions

Ten major assumptions provided the foundation upon which the Nathan Report made its forecasts:

1) NTSC Compatibility - HDTV technology will not make NTSC receivers obsolete.

2) High-End Market Niche - HDTV technology will first be commercialized as a high-end product in large screen sizes (30"+) -- eventually absorbing the 26-29" segment of the market.*

3) U.S. Production - Due to their size, HDTV sets will be produced in the United States.

4) Timing - Significant levels of HDTV sales will begin in 1993.

5) Consumer Acceptance - The benefits of HDTV, including wide aspect ratio, crisp pictures, and CD quality sound will attract a significant portion of the viewing public.

6) Software Availability - Compatible programming and software will be available as HDTV products are introduced in the market.

7) Price Comparable to Presently Available IDTV and EDTV Sets - HDTV sets will initially be sold at $2,500 retail with prices rapidly declining.

8) Domestic Content will constitute 70 percent of the manufacturing cost of an HDTV set.

9) Stable Long Term Economic and Social Trends - Long-term trends in GNP growth, household formation, and other factors influencing TV sales will continue throughout the forecast period.

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*The EIA Marketing Services Department estimates annual sales could soon reach 170,000 to 200,000 for 30-inch and over sets at a retail price exceeding $2,000 (excluding projection TV).

10) Related Technological Innovations (such as IDTV and EDTV) will not materially affect the production and sale of HDTV.

B. EIA Nathan Report Summary

The Nathan Report came to the following conclusions:

The development of high definition television (HDTV) will affect the nature of the U.S. color television manufacturing industry significantly. The new technology will have an effect on virtually all segments of the television industry: television program and software production, transmission systems, and reception and display equipment. HDTV will penetrate the marketplace rapidly with ten percent of U.S. households owning one HDTV set four years after market introduction. This rate of penetration will be greater than the historical acceptance of color TV or VCRs. Twenty-five percent of U.S. households will own one HDTV set by the end of the 20th century. By 2003, 13.1 million HDTV sets will be sold in the United States -- sales roughly equal to the number of color televisions produced and sold in the United States in 1987. Ninety-two percent of these 13 million HDTV sets (12.1 million) will be manufactured in the United States.

HDTV will be a substitute product for current NTSC sets rather than a unique, entirely new product. Initially, HDTV's market share will be the 30-inch and larger screens. Increasingly, HDTV will dominate large screen sales (26-inch and larger) and eventually penetrate the 20- to 25-inch market -- achieving a 32.5 percent market share of all color TVs in 2003. The retail value of these sets will be more than 3.6 times the retail value of U.S. color television production in 1987 with at least 85 percent of the retail value expected to come from the U.S. TV pipeline.

The product mix will be affected by the introduction of HDTV. As HDTV's market share increases, it has the potential to contribute $6.2 billion to U.S. GNP in 2003. In the year 2003, the TV industry will continue to employ 230,000 workers -- about the same number of workers currently employed in the TV pipeline. HDTV will make additional contributions through substantial opportunities created in the design, development, installation, and operation of communications transmission equipment and delivery systems.

C. The EIA Report in Retrospect

If the EIA Report were to be released today, one of the initial assumptions of the study would be altered. As it becomes increasingly obvious that the FCC will not be in the position to set a transmission standard before late 1992 at the earliest, the assumption that significant sales will be seen in 1993 is unlikely. Set manufacturers require 18 to 24 months between the time a standard is set and significant production can begin, thus a more realistic time frame for HDTV introduction in this country would be 1995.

THE CBO REPORT

EIA applauds the work of the Congressional Budget Office in analyzing the three major private forecasts on the market for high-definition television. Overall, EIA agrees with the CBO's reasoned analysis of the HDTV forecasts. Such an analysis, from an objective source, provides the type of forethought that EIA believes to be essential in formulating the debate which will result in policy decisions on the federal government's role in HDTV development in the United States.

I would like to take this opportunity to address two claims regarding HDTVs that are made on a recurring basis. The first is that HDTV will use flat panel displays, rather than picture tubes, thus involving more semiconductor content than NTSC sets contain. The second claim is that HDTV will merge with computer workstation technology.

1. Flat Panel Displays

Much speculation centers on the idea that flat panel displays will provide the screen medium for HDTV rather than what is currently in use -- cathode ray tubes (CRTs). This may or may not be the case. However, I have been in the electronics industry for 30 years and for most of that time I have been hearing that flat panel displays are just five years away. As it stands today, CRTs are likely to be the screen medium for HDTV in the forseeable future. If flat panel displays are to become the norm in HDTV, they will need to meet some rigid standards that will be tested against a CRT benchmark: quality, color fidelity, contrast ratio, grey scale, brightness of picture, lifespan, and finally -- cost. Only if and when such standards are met will flat panel displays become the norm in HDTV sets. Flat panel display technology is a suitable technology for R&D funding as the company that first perfects this technology will have an advantage in the consumer and other sectors of the electronics industry.

As for the semiconductor content of flat panel displays, the assumption that matrix addressed flat panel displays will use particularly large quantities of integrated circuits may be invalid. One of the more promising flat panel technologies is liquid crystal (LCD's). Within a few years, the matrix drivers for LCD's will be fabricated simultaneously with the pixel transistors on the glass. This will greatly reduce the digital IC's required.

2. The Merging Between Workstations and HDTV

Workstations are high-end personal computers intended as productivity improving devices for professional "knowledge workers." They include high resolution color displays, fast processors, massive memory, and special applications programs.

Workstations are priced between 5,000 and 30,000 dollars. Their productivity-improving potential has made them indispensable. Essentially no engineering group engaged in product design can be competitive without them. The alternative is to employ many more engineers and take much longer to complete projects.

The fundamental nature of these machines includes high resolution displays of modest size, tremendous quantities of memory, fast processors, and ergonomic factors meant to minimize fatigue over long hours of work. In at least one sense, they are inadequate for HDTV and in several other ways they are overkill.

The displays for workstations are too small for HDTV. Preliminary consumer studies, one of which has been cited in the CBO Report, indicate that consumers cannot tell the difference between NTSC and HDTV when viewed from more than five picture heights. Since home viewing distance is determined by viewing room size and furniture placement, this translates into the need for a large screen: sixty, seventy, perhaps eighty inches measured diagonally. Brightness of consumer displays must be much higher than is required of workstations. Furthermore, the dim ambient light environment needed for workstations works against the traditional consumer preference for watching TV in a well-lit room. Workstation environments are designed to suit the workstation. Workstations are viewed from a distance of a foot or so. Nineteen-inch or twenty-five inch diagonal measure is more than adequate for use as a computer workstation display. Ultimately, the nature of the displays used in workstations and in consumer HDTV will likely always remain very different.

Workstation processing is very generalized and extensive. While HDTV will require substantial signal processing, it will be very specialized and very different from that signal processing employed in workstations. The primary emphasis of HDTV signal processing is bandwidth reduction and motion artifact minimization. A thirty MegaHertz studio signal needs to be squeezed into significantly less channel space. Technical trade-offs must be made so that the resulting motion artifacts will be acceptable. For terrestrial broadcast, this must be accomplished with a minimum of interference to and from existing television services. While one cannot deny that there is a commonality of technologies, one must understand that the two technologies are not directly related.

EIA'S VIEWS ON HDTV AND COMPETITIVENESS

EIA has closely and extensively examined the issue of HDTV and U.S. competitiveness. Its views on this issue are contained in the attached report: "Consumer Electronics, HDTV and the Competitiveness of the U.S. Economy" which was originally submitted on February 1, 1989 to the House Telecommunications and Finance Subcommittee.* The following comments supplement the attached report.

A. Competitiveness and the Electronics Industry

It is EIA's view that the U.S. electronics industry prospers within a healthy economic environment that encourages investment in research and development and minimizes interference with free market transactions.

With almost two million U.S. employees and $248 billion in 1988 U.S. sales, the American electronics industry is competitive. It has benefited from several factors unique to the U.S. Our excellent university system, a free market economy, sustained economic growth, research and development tax credits, a large marketplace, a creative and diligent workforce and the flexibility permitted by international purchasing have all contributed to the success of the U.S. electronics industry.

While these factors have contributed to the electronics industry's health, other factors clearly jeopardize our industry's future success and cut against the decision of a company to invest in U.S. research, development, and manufacturing. The higher U.S. cost of capital fueled by the budget deficit, increasing burdens on employers through mandated worker benefits, a relative paucity of scientists and engineers, the questionable permanence of the R&D tax credit, an increasingly ill-prepared entry-level work force and the vagueries of state and federal regulation all increase the risks for a company planning to invest in U.S. facilities.

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*Appendices of this report are not included in the attachment.

No matter how well the U.S. does in terms of increased productivity and its strength in the U.S. market, macroeconomic considerations, especially currency fluctuations, interest rates, and the budget deficit have all had a significant impact on the electronics sector. As a case in point, let me give you an example of how macroeconomic factors impact the electronics industry.

A commonly cited statistic is that between 1984 and 1987 the U.S. electronics share of world production dropped from 50.4 percent to 39.7 percent while Japan's share increased from 21.3 percent to 27.1 percent. These grim numbers primarily reflect a 50 percent decline in the yen-dollar relationship over this time period. In fact, measured in local currencies, U.S. production of electronics grew at a compounded annual growth rate of 3.59 percent from 1984 to 1987 while the Japanese electronics industry growth rate during this period was actually lower at 3.32 percent. Thus, a statistic that makes the electronics industry appear to be a complacent old giant in the throes of a severe illness, actually masks the positive fact that the U.S. electronics industry is hungry and running hard to compete.

Simply put, EIA views competitiveness as a national concept concerned with economic performance of nations, not companies. Accordingly, EIA supports numerous policies which would enhance national competitiveness. Specifically, EIA recommends that the Congress act to:

1. Reduce the Deficit - Adoption of a gradual deficit reduction plan would decrease the nation's dependence on foreign capital and increase the national savings rate.
2. Shift Federal Spending toward education and worker training, infrastructure and commercial science and technology.
3. Change Tax Laws to Encourage Investment - Reintroduction of the investment tax credit and a graduated capital gains tax would provide strong investment incentives.
4. Make the R&D Tax Credit Permanent - Studies suggest the R&D tax credit is a major factor in private R&D and that societal returns from such R&D exceed the returns to the financing firms.
5. Relax Antitrust Restrictions on Joint Production to encourage joint manufacturing among private firms.

These actions will assist all industries in staying healthy and in keeping the U.S. competitive.

B. Competitiveness and HDTV

Much has been said about the importance of HDTV to U.S. competitiveness. Increasingly, the competitiveness of the nation has become associated with its ability to emerge a winner in the HDTV race. This focus is misleading, oversimplifies the problem and is potentially harmful.

First, it ignores the concept of competitiveness as a nationwide issue -- totally distinct from the competitive position of a specific product or activity. As such, a narrow focus on HDTV detracts from the need to find solutions for major economy-wide problems of primary importance to national competitiveness.

Second, as the ~~CBO~~ Report on HDTV predictions suggests, there is disagreement on the effect that HDTV will directly have on other sectors of the electronics industries. It is important to understand the real benefits HDTV will provide related industries where the U.S. is a world leader such as in fiber optic communications, movie and entertainment creation, transmission and delivery systems, and television production equipment.

Third, the misplaced symbolism of HDTV as a recipe for U.S. competitiveness encourages line-drawing between companies on the basis of ownership which could actually discourage investment in American research, development and manufacturing. For example, in the HDTV debate, Zenith is pointed to as the last American consumer electronics company. Despite this inaccuracy (Tandy, Curtis Mathes, Wells-Gardner, and others are American consumer electronics companies) it ignores the international nature of not only all major consumer electronics companies but all major electronics companies. Zenith, for example, manufactures many of its TVs in Mexico while Thomson, Philips and Sony contribute significantly to U.S. competitiveness through their U.S. operations. Similarly, U.S. companies are increasingly seeing a healthy share of their profits deriving from the globalization of their manufacturing and R&D. As Robert B. Reich of Harvard's Kennedy School of Government noted in the July 24 New York Times:

"We are going to wake up soon to the fact that a lot of American companies are no longer American." Statistics bear this out; nearly 17 percent of total U.S. corporate assets are now overseas and, in 1988, U.S. companies invested $42 billion in plant and equipment abroad. HDTV public policy alternatives would better be focused on the locale of a company's R&D and its creation of U.S. jobs rather than focusing on a company's headquarters location in judging contributions to U.S. competitiveness goals.

EIA FUNDING RECOMMENDATIONS

If policymakers favor government funding for HDTV, EIA would suggest certain guidelines to insure maximizing U.S. tax dollar returns:

1. Public funding of HDTV should focus on generic technological research as progress on generic research would benefit several industries. EIA suggests R&D consortia for integrated circuitry, large displays and electronic manufacturing technology.
2. Publicly funded research should be performed in the U.S.

CONCLUSION

The spotlight on HDTV will have been helpful if it sheds light on the broader issues of national competitiveness. EIA hopes that HDTV will be the catalyst for Congress to address the tough economy-wide issues and for American companies to adopt a long-term vision of their economic well-being.

EIA/ATV COMMITTEE -- COMPANY NAMES

ADC Telecommunications
Alcatel North America
AMP, Inc.
AMPEX Corporation
ANIXTER
AT&T
AT&T Bell Laboratories
AT&T Federal Systems
AVX Corporation
Belden Wire and Cable
Bellcore
Corning Glass Works
GE Americom
General Instrument Corporation
GTE Service Corporation
Harris Corporation
Hitachi, Ltd.
Hitachi Sales Corp. of America
Hughes Communication, Inc.
Hughes Network Systems
IBM Corporation
Magnavox - CATV Systems Company
Matsushita Electric Corp. of America
Mitsubishi Electric Sales America, Inc.
Motorola, Inc.
NEC Home Electronics (USA), Inc.
Norden Systems, Inc. (United Technologies)
North American Philips
Panasonic Company
Panasonic Technologies, Inc.
Philips Consumer Electronics
Philips Laboratories
Rockwell International Corporation
Scientific-Atlanta, Inc.
Siecor Corporation
Sony Corporation of America
Thomas Electronics, Inc.
Thomson Consumer Electronics, Inc.
Toshiba America, Inc.
TRW, Inc.
Varian Associates, Inc.
Westinghouse Circle
Zenith Electronics Corporation

OBSERVERS

Collier, Shannon, Rill and Scott
Dotronix, Inc.
Molex, Inc.
National Association of Broadcasters
Photonic Technologies
U.S. Precision Lens, Inc.

Consumer Electronics,
HDTV
and the
Competitiveness of the U.S. Economy

Submitted by:

The Electronic Industries Association's
Advanced Television Committee

to

Congressman Edward Markey (D-MA) Chairman,
House Telecommunications and Finance Subcommittee

February 1, 1989

PREFACE

This report is submitted by the Electronic Industries Association's Advanced Television Committee (EIA/ATV Committee) in response to a September 7, 1988 request by House Telecommunications and Finance Subcommittee Chairman Edward Markey to EIA/ATV Committee Chairman Sidney Topol. This report addresses many of the questions raised that day by Chairman Markey and his colleagues on the Subcommittee as well as questions raised in Congressman Markey's December 7, 1988 letter to Mr. Topol.

The EIA and its ATV Committee believes it is uniquely suited to address these questions. EIA and EIA's ATV Committee include developers, manufacturers, sellers and installers of studio, broadcast, transmission and consumer equipment. EIA is the only association representing all facets of electronics hardware manufacturing and its members sales account for over 85 percent of the dollar volume of electronics manufactured in the United States.

Recognizing the importance of advanced television ("ATV"), EIA has formed a committee which has, for over a year, considered all public policy and technical issues associated with ATV. The EIA/ATV Committee includes representatives from the broad spectrum of the electronics industry.* Participating in the EIA/ATV

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* The EIA/ATV Committee is chaired by Sidney Topol, Chairman of the Board of Scientific-Atlanta, Inc. Companies participating in the Committee include: ADC Telecommunications; ANIXTER; AVX Corp.; AMP, Inc.; AT&T; AT&T Federal Systems; AT&T Bell Laboratories; Alcatel, NA; Belden Wire & Cable; Bellcore; Cincinnati Electronics Corp.; Cooper Industries; Corning Asahi Video Products Co.; Corning Glass Works; GE Americom Communications, Inc.; Harris Corp.; Hitachi Sales Corp. of America; Hughes Network Systems; Hughes Communications, Inc.; IBM; Imaging & Sensing Technology Corp.; Magnavox-CATV Systems Co.; Matsushita Electric Corp.; Mitsubishi Electric Sales America, Inc.; Motorola, Inc.; NEC Home Electronics (USA), Inc.; North American Philips Corp.; OI-NEG IV Products, Inc.; Panasonic Technologies, Inc.; Philips Consumer Electronics; Quasar Com-

Committee are EIA members, including members of the EIA's affiliate—the Telecommunications Industry Association (TIA)**, as well as non-EIA members.

The EIA/ATV Committee approached this task with urgency and seriousness. The Committee believed, and continues to believe, that Chairman Markey's request reflects a growing national concern that HDTV provides our country with both a fundamental challenge and a tremendous opportunity.

Unanimously, the EIA/ATV Committee agreed that it should address the issue of HDTV and competitiveness directly, thoughtfully, and comprehensively. This was no easy task. The EIA has previously addressed the issues of competitiveness and HDTV, but not in tandem. While the EIA for several years has spoken, testified and lobbied on several issues affecting U.S. competitiveness, it has only recently addressed issues involving HDTV. Its focus on HDTV has been primarily oriented to developing consensus on technical issues so that a marketable product would be developed in a timely manner.

To meet the challenge presented by Chairman Markey, the EIA/ATV Committee has taken three key steps, each involving significant expenditures of resources.

First, Committee Chairman Topol appointed a working subcommittee composed of diverse industry sectors and

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pany; Scientific-Atlanta, Inc.; Siecor Corp.; Sony Corp. of America; TRW, Inc.; Thomas Electronics, Inc.; Thomson Consumer Electronics; Toshiba America, Inc.; Varian Associates, Inc.; U.S. Precision Lens, Inc.; and Zenith Electronics Corp.

Although a member of the EIA/ATV Committee, Zenith Electronics Corp. is filing its own response to Congressman Markey's request and does not necessarily share in any or all of the viewpoints contained herein.

** The Telecommunications Industry Association (TIA), is a full service national trade organization with nearly 600 members that provides materials, products, systems, distribution services and professional services to the telecommunications industry in the United States and countries around the world. The TIA represents the telecommunications industry in association with the EIA.

interests to forge an industry-wide consensus on all critical issues. The subcommittee included different product manufacturers with different perspectives but, fortified by real world expertise in the development, manufacturing and selling of electronics hardware, the subcommittee reached a remarkable degree of consensus on almost every major issue.

Second, upon receipt of Congressman Markey's request, the EIA redirected the process, focus and timetable of an ongoing study of U.S. television manufacturing by the economic consulting firm of Robert R. Nathan and Associates. Chapter four of the Robert R. Nathan report, which is referred to in this document, was released prior to public release of chapters one through three to provide reliable and usable data for use by policymakers.

Finally, but of critical importance to the success of this project, the EIA/ATV Committee reached out to several eminent scholars from the Berkeley Roundtable on the International Economy (BRIE). These professionals uniquely combine expertise, academic objectivity, and the highest reputation with which to address the issues of electronics and competitiveness. Although this report reflects EIA's views, much of the research, prose, ideas and comprehensive analytical approach are attributable to these scholars: Professors Michael Borrus, Steven Cohen, Jeffrey Hart, Laura Tyson and John Zysman. We are grateful for their contribution.

SIDNEY TOPOL, Chairman
EIA/ATV Committee

PETER MCCLOSKEY, President
Electronic Industries Association

ALLEN FRISCHKORN, President
Telecommunications Industry
Association

February 1, 1989

TABLE OF CONTENTS

	Page
EXECUTIVE SUMMARY	ix
Policy Initatives to Restore U.S. Competitiveness	x
Recommendations to Guide HDTV Policies	xii
INTRODUCTION	1
Reasons for Interest in HDTV	1
THE MEANING OF NATIONAL COMPETITIVENESS	4
EVIDENCE OF WEAKENING U.S. COMPETITIVENESS	7
Trade Deficit	8
Sluggish Productivity Growth Rate	9
Decline Of Growth Of Wages And Real Income	9
Slow Pace Of Technological Innovation And Diffusion	9
Low Rates Of Investment	12
GENERAL POLICIES TO IMPROVE U.S. COMPETITIVENESS	13
Increase Investment and Savings Commitment	13
Shift Federal Spending to Education, Worker Training, Infrastructure, and Commercial Science and Technology	16
Tax Policy	18
Characteristics of Public-Private R&D Consortia to Encourage Competitiveness	21
Amend 1984 National Cooperative Research Act	22
Recap of Pro-Competitiveness Policy Recommendations	24

TABLE OF CONTENTS—Continued

Page

THE ROLE OF ELECTRONICS IN U.S. COMPETITIVENESS 25

Linkage Impacts and Technological Spillovers........ 26

THE ROLE OF CONSUMER ELECTRONICS WITHIN THE ELECTRONICS COMPLEX 31

Upstream Effects 31

Downstream Effects 32

Manufacturing Effects 33

THE POTENTIAL IMPORTANCE OF HDTV TO CONSUMER ELECTRONICS 35

Current U.S. Set and Tube Production 38

HDTV Economic Forecast 42

SPECIAL POLICIES TO PROMOTE U.S. PARTICIPATION IN HDTV MARKETS 44

HDTV Standards Policy 44

Meeting the Technological Challenge 47

SUMMARY OF REPORT 50

TABLE OF ATTACHMENTS

TABLE 1 Page

Growth Of Real Exports Of Goods And Services In The OECD Area 51

TABLE 2

Growth Of Real Imports Of Goods And Services In The OECD Area 52

TABLE 3

Competitive Positions Of Nations 53

TABLE 4

Productivity Trends In Selected OECD Countries.. 55

TABLE 5

International Manufacturing Costs 57

TABLE 6

Total Defense And Non-Defense R&D Shares Of GNP By Nation 58

TABLE 7

Profits And Investment In The Business Sector Of Nations 59

TABLE 8

U.S. Trade Balance By Product Category 61

FIGURE 1

New Plant & Equipment Expenditures By Business 62

FIGURE 2

Productivity Vs. The Capital-Labor Ratio In Manufacturing 63

TABLE OF ATTACHMENTS—Continued

FIGURE 3 Page

U.S. Net Domestic Investment As A Percent Of GNP 64

FIGURE 4

U.S. Balance Of Trade 65

FIGURE 5

U.S. Industry Color Tubes/Kits Imports & Exports 66

APPENDIX A

Legislative Proposal—"National Cooperative Research And Commercialization Act" 1a

APPENDIX B

Standards Setting 20a

APPENDIX C

Fiber Optics & HDTV Backgrounder 25a

EXECUTIVE SUMMARY

In recent months the question of whether the U.S. will occupy a competitive position in the emerging HDTV market and related technologies has become symbolic of the broader question of how the U.S. can regain its competitive strength in world markets. As HDTV has become perceived as a symbol of the nation's competitive challenges, Congressional enthusiasm for national policies to promote U.S. participation in HDTV has mounted, not simply because of the anticipated production, employment and trade effects of such participation, but because of the anticipated spillover effects on U.S. competitiveness more broadly defined.

The premise of this Report is that competitiveness is primarily an economy-wide issue, most effectively addressed by broad-based or aggregate policy measures that are designed to promote investment in physical plant, knowledge, and human capital throughout the economy. Without such aggregate policies, industry-specific policies aimed at HDTV or at any other individual industrial activity deemed to be of strategic significance will fail to improve the nation's competitiveness. In combination with the appropriate aggregate policies, judicious industry-specific policies aimed at industries with important linkages and technological spillovers for a wide variety of industries may have a beneficial effect on national competitiveness.

Segments of the electronics industry, particularly the semiconductor industry—and in the future, the HDTV industry—provide positive technological spinoffs and beneficial linkage effects for other industries and related technologies. Thus there may be a public rationale for policy measures to promote these activities. This public rationale must be distinguished from the rationale of anticipated private profits, production, and employment that motivates private actors as they decide whether and how to exploit perceived market opportunities in semiconductors, HDTV or any other electronics activity.

Section I provides an introduction to the Report. Sections II and III focus on national competitiveness, broadly defined as the ability of the nation to realize balanced trade over time while simultaneously increasing the real incomes of its citizens. Several indicators, including the trade and current account imbalances, sluggish productivity and real income growth, the pace of technological innovation and diffusion, and the low investment rate indicate that American competitiveness has declined.

To restore national competitiveness, seven aggregate policy initiatives are recommended in Section IV:

1. The adoption of a gradual deficit reduction plan to decrease the nation's depedence on foreign capital and to increase the national savings rate. The goal of such a plan should be approximate budget balance by 1993 in accordance with Gramm-Rudman guidelines.
2. A shift in the composition of federal spending toward education and worker training, infrastructure, and commercial science and technology.
3. A change in the nation's tax laws to encourage investment. In particular, the re-introduction of an investment tax credit and a graduated capital gains tax, adjusted for the period of time over which gains are realized, should be adopted. The relationship between private saving and taxation should also be studied to determine whether existing disincentives to saving should be eliminated or new incentives to saving added.
4. The introduction of a permanent research and development (R&D) tax credit. Existing studies suggest that such a credit has a significant effect

on the amount of R&D done by the private sector and that the social returns from such R&D far exceed the private returns of the firms financing it.

5. The use of government funds to encourage the formation of public-private consortia for middle-ground or generic technology projects. Sematech is an example of such a project, but there may be other more useful models for consortia. Public funds should only supplement and not substitute for private funds for such projects. The initiative for such projects should come from the private sector and the private sector should be responsible for their management and operation.
6. The further relaxation of existing antitrust restrictions on cooperative research and development activities among private firms. In particular, the National Cooperative Research Act should be amended to encompass joint production as well as joint research activities under certain circumstances.
7. International negotiation and the nation's trade laws should be used to press for greater openness in international markets and to insure fair competition in both international and U.S. markets.

Sections V and VI of the Report examine the influence of the electronics sector, especially the semiconductor and consumer electronics industries, on national competitiveness. Due to significant technological spillovers and linkages between these industries and the rest of the economy, and their effects on national output, employment and trade trends, these industries have special significance for preserving the nation's long-term competitiveness.

Section VII of the Report examines the potential importance of HDTV to the consumer electronics industry.

A variety of studies indicate that HDTV products, despite their initial high price, are likely to prove attractive to consumers and to provide growing market opportunities for consumer electronics producers in the future. Beyond these market opportunities, there are reasons to believe that HDTV could be a factor in the development of future technologies in computers, telecommunications, and defense electronics. Thus, the United States should participate as much as possible in the development and commercialization of HDTV products.

Section VIII of the Report considers sector-specific policies to promote U.S. participation in the emerging HDTV market. Such policies should be designed to maximize the positive spillover benefits from HDTV for the rest of manufacturing, particularly related electronics industries such as the semiconductor industry. Three general recommendations to guide the development of policies for HDTV are made:

1. Policies should promote, not impede, the expeditious adoption of standards. Electronics generally and TV manufacturing in particular are global industries. If the U.S. delays, the rest of the world will proceed to advance technologically to the relative disadvantage of technology for the U.S. market.
2. To the extent that public funds are made available for the promotion of HDTV, they should be focused on generic technological problems the resolution of which will benefit a large number of industries. For this reason, R&D consortia for integrated circuitry, large displays and electronic manufacturing technology would seem to be good candidates for public funding.
3. Foreign-owned U.S. producers already play a leading role in the television industry. Due to their investment in manufacturing and R&D fa-

cilities in the United States they are active in many of the technologies related to successful HDTV participation. Any policy efforts that attempt to exclude these producers will delay the development and introduction of HDTV technology in the U.S. and discourage foreign producers from expanding their production and R&D operations here. In the case of HDTV technological consortia, it is quite likely that foreign-owned firms will want to participate and that it is in the interests of the United States to encourage their participation.

4. Finally, competitiveness is a national concept; concerned with the economic performance of nations, not companies. **According to this perspective, domestic firms can adopt production, investment, location and sourcing strategies that weaken national competitiveness, while foreign-owned firms operating in the U.S. can adopt comparable strategies that actually strengthen the competitiveness of the United States.**

I. INTRODUCTION

There is widespread interest in HDTV for three reasons.

First, the HDTV market is projected to be large, and the potential effects of HDTV on national production, employment, and trade performance are estimated to be substantial.

Second, HDTV is viewed by some as a way for the U.S. to re-enter television and VCR markets—which U.S.-owned firms, with few exceptions, have virtually abandoned. According to some observers, the costs of this abandonment of a major part of the consumer electronics market have been lost production, sales, employment, and a dramatic deterioration in the U.S. trade balance in electronics. As we shall see later in this report, these costs have been greatly exaggerated.

Third, there is growing policy concern about U.S. participation in HDTV due to the technological spillovers that HDTV production may generate in a variety of related activities, including the development of new semiconductor componentry and new video display technology. These spillovers could affect the American competitive position in a variety of important industries, including computers and advanced telecommunications equipment. Spillovers with applications to defense are also considered likely.

It is claimed that there have been additional costs in linked industries such as semiconductors. The dramatic drop in the U.S. share of world semiconductor sales is, in part, the result of the increasing content of semiconductors in consumer electronics (televisions, radios, disk players, electronic games, etc.), a business which companies based in Japan dominate. At least 35 percent of Japanese consumer-electronics production has been sold to the U.S., and roughly as many semiconductors have entered the U.S. in consumer-electronics products as have been sold to the U.S. directly. But recapturing semiconductor market shares through a revived U.S. consumer electronics industry will not be easy because that industry will continue to be competitive and thus will behave more or less as it has in the past—companies will source their electronic components from those firms which provide the optimal combination of price, performance, and quality.

To many the question of whether the U.S. will be able to occupy a competitive position in the emerging HDTV market and related technologies has become symbolic of the broader question of whether the U.S. will be able to regain its national competitive strength. Increasingly the competitiveness of the nation has become associated with its ability to emerge a winner in the HDTV market This symbolism is seriously misleading.

A fundamental premise of this Report is that competitiveness is primarily an economy-wide issue and is logically distinct from the competitive position of the nation's producers in a particular industry or activity A corollary is that the most effective policies to improve national competitiveness must address broad-based problems, such as the low rates of national saving and investment, the high cost of capital, an inadequately educated and skilled workforce, and insufficient public support for generic or middle-ground R&D, all of which adversely affect private sectors across the industrial spectrum.

An aggregate perspective, however, overlooks the reality that certain industries or activities may contribute more than others to national competitiveness over the long run. And there is evidence to suggest that the electronics sector, broadly defined to include the semiconductor industry, the telecommunications industry, the computer industry, and at least segments of the consumer electronics industry, falls into this category. For the reasons identified in this Report, many policymakers and industry participants believe that the long-term competitive health of many parts of the U.S. electronics sector will be adversely affected by a U.S. competitive failure in HDTV. One objective of this Report is to evaluate this position.

Even if U.S. policymakers and industry representatives are persuaded that the U.S. competitive position in the emerging HDTV area is important to the nation's long-run competitiveness, many unresolved policy issues remain. Two such issues are of paramount importance. The first arises because of the particular ownership configuration of television producers in the U.S. Currently, most producers are foreign-owned, and some of the foreign-owned facilities operating here have broad-based activities, ranging from R&D to distribution. Many conduct extensive R&D activity in the United States, an activity which should be encouraged by government policy.

This raises a fundamental question that must be addressed before policy decisions are made, to wit: if the objective of policy is to foster U.S. participation in HDTV, will participation by foreign-owned firms operating from U.S. locations support this objective? In other words, does U.S. participation mean participation by domestically-owned firms regardless of where they locate their production, employment and research facilities, or does it mean participation by foreign-owned firms operating in the U.S.—or perhaps does it mean a combination of both? The HDTV issue reveals the increasingly global nature of many high-technology industries and the difficulties of making public policies to foster national participation. To limit such policies to domestically-owned companies is likely to delay the development and introduction of HDTV technology in the U.S. market and to discourage foreign-owned producers from expanding their production and R&D operations in the U.S.

A second basic policy question is whether policies specifically targeted to HDTV are required to foster U.S. participation. however defined. Perhaps a combination of broad-based pro-competitiveness policies, such as a change in the monetary and fiscal mix with lower interest rates, an R&D tax credit, further relaxation of antitrust limitations on joint R&D activity, and continued efforts to insure fair competition in U.S. and international markets is all that is needed. Certainly, as this Report argues, without a change in at least some of these broader policy areas, it is unlikely that all the beneficial effects of U.S. participation in HDTV on U.S. competitiveness will be realized.

Finally, even if special policies to foster U.S. participation are required, what form should they take? What are the appropriate roles of standards-setting, R&D consortia, Defense Department spending, and other policies?

II. THE MEANING OF NATIONAL COMPETITIVENESS

During the last several years, the dramatic and sustained deterioration in the U.S. trade deficit has created growing concern over American competitiveness. Indeed, competitiveness, a concept that did not even exist in national policy discussions five years ago, has become a buzzword. Business, labor, education, and government leaders speak of the competitiveness challenge confronting the United States and offer a potpourri of sometimes conflicting policy solutions. Initiatives in such diverse areas as trade legislation, educational reform, and taxes are defended or criticized on the basis of their effects on U.S. competitiveness.

Like most buzzwords, competitiveness has symbolic significance. It draws national attention to the undeniable fact that the position of the United States in the world economy is weakening. America can no longer rest comfortably in the belief that it will continue to be the leading economic power in the world. Although still the largest and one of the richest economies, the United States has lost ground compared to many countries with which it competes in world trade. To some extent, of course, this was inevitable. As the other developed countries rebuilt from war destruction and as many developing countries introduced ambitious development programs —helped by American funds and American technology— some catching-up was inevitable. But the pace and extent of the catch-up—or to put it differently, the pace and extent of the relative decline in the U.S. position—were not inevitable. And significantly for the future, there is no inevitability of a continued decline in the U.S. position.

If competitiveness is to have more than symbolic significance, if it is to become a reliable guide for policy, it must be properly defined. For the purposes of this Report, competitiveness is defined, as it was in the Report of the President's Commission on Industrial Competitiveness and more recently by the Council on Competitivess, as "the degree to which a nation, under free and fair market conditions, produces goods and services that meet the test of international markets while simultaneously maintaining and expanding the real incomes of its citizens."[1] There are four important points about this definition that should be emphasized.

First, competitiveness implies an ability to compete in international markets, with balanced trade over the long run, without an associated decline in real wages, and without a continued decline in the value of the dollar that would cause falling real wages over time. Competitiveness is not simply the ability to sell abroad or to maintain a sustainable trade position at some exchange rate. The very poorest nations often boost exports just by devaluing their currencies. The consequences, however, are sharp declines in relative wages and relative standards of living, declines that are at odds with national competitiveness as defined here.

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[1] President's Commission on Industrial Competitiveness, *Global Competition: The New Reality* (Washington, D.C.: USGPO, December 1984); Council on Competitiveness, *America's Competitive Crisis: Confronting the New Reality* (Washington, D.C.: March 1987).

Second, competitiveness implies an ability to compete in free and open markets. In this sense, neither a worsening of U.S. trade performance occasioned by unfair trade measures abroad nor an improvement occasioned by protectionist trade measures at home is a sign of a real change in U.S. competitiveness.

Third, competitiveness is a concept related to economy-wide performance. Policy discussions sometimes focus on the competitive position of particular U.S. industries in world trade. Often, the competitive performance of certain industries, such as the U.S. semiconductor or consumer electronics industry, is taken as indicative of U.S. competitiveness broadly understood. While certain industries or activities may be especially important to national competitiveness—for reasons discussed later in this Report—competitiveness is best understood as an economy-wide concept rather than as a sectoral or industrial one. And the most effective policies for improving national competitiveness are broad-based policies aimed at strengthening national productivity and technological performance—the two basic determinants of national competitiveness.

Finally, competitiveness is a national concept. It is concerned with the relative economic performance of nations, not companies. The focus on national economic performance means that indicators of national competitiveness, rather than indicators of the competitiveness of individual firms whose headquarters are in one nation but whose production and distribution facilities are internationally located, are the relevant subject for policy concern. According to this perspective, **domestic firms can adopt production, investment, location and sourcing strategies that weaken national competitiveness, while foreign-owned firms operating in the U.S. can adopt comparable strategies that actually strengthen the competitiveness of the United States.**

Just as the choices of American multinationals have contributed to the growing competitivenes of the East Asian newly industrializing countries, so the choices of foreign multinationals operating in the United States may contribute to the restoration of American competitiveness. In short, there is no simple or necessary relationship between the ownership of firms operating in a nation and its competitiveness as defined here.

III. EVIDENCE OF WEAKENING U.S. COMPETITIVENESS

The long-term weakening of U.S. competitiveness does not show up in any single economic indicator but rather is suggested by several different ones. Among the most meaningful indicators of national competitiveness are: the trade and current account balances; the productivity growth rate; the rate of growth of wages and real incomes; the pace of technological innovation and diffusion; and the rate of investment.[2] The evidence on these indicators presented in Tables 1 through 7 and Figures 1 through 3 reveals an erosion in the U.S. competitive position in recent years. The following discussion presents a brief analysis of each of these indicators.

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[2] The Council on Competitiveness has developed a set of four competitiveness indicators comparing U.S. performance with that of the other advanced industrial countries. The four indicators include: the growth of the standard of living (measured as the gross domestic product plus the current account per employed worker); the growth of labor productivity in manufacturing; the share of world export markets; and the investment rate. Although these indicators differ somewhat from those discussed in this Report, there is substantial overlap between the two. For a discussion of the Council's indicators, see the Council on Competitiveness, *Competitiveness Index* (Washington, D.C.: July 1988).

Perhaps the most often cited indicator of the nation's competitive challenge is the dramatic deterioration in the merchandise trade deficit from $25.5 billion in 1980 to $160.3 billion in 1987. During the same period, the U.S. current account declined from a surplus of $1.9 billion to a deficit of about $154 billion.[3] Given present policies and exchange rates, no respectable economic analysis shows the current account deficit falling much below $100 billion over the next several years. At this rate, U.S. external debt will hit $1 trillion—perhaps as much as 20-25 percent of GNP—sometime in the early 1990s.

The sharp fall in the value of the dollar since late 1985 has had a beneficial effect on external performance. In real terms, U.S. exports grew much more rapidly than exports from the other developed counries in 1986 and 1987 (see Table 1). U.S. import growth continued to be surprisingly strong in these years despite the dollar's decline (see Table 2). Since January 1988, however, imports have begun to level off in real terms. Together, export growth and import stagnation in real terms should contribute to a significant decline in the trade deficit in 1988—perhaps by as much as $30-$40 billion from the record high of 1987.

The drop in the dollar has meant a real boost in the price competitiveness of U.S. exports (see Table 3). As a result, the declining share of the U.S. in world export between 1980 and 1986 was reversed in 1987. But U.S. producers and policymakers cannot and should not rely on further adjustments in the dollar's value to restore the nation's productivity and real income growth and to bolster its technological performance.

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[3] In 1987, the current account deficit hit 3.4 percent of GNP, the highest rate since the U.S. was last a net debtor nation at the end of the nineteenth century.

Another obvious indicator of the nation's eroding competitiveness is its sluggish productivity growth rate. Despite the pickup in productivity growth in recent years, the U.S. continues to be a laggard in the productivity growth race (see Tables 4 and 5). In some critical sectors, like automobiles, semiconductors, and consumer electronics, we are no longer the productivity leader.

A poor productivity record has translated into a poor record on wage and income growth. Depending on the accounting methodology and dates used, real per worker earnings have either barely risen, stagnated or fallen during the last eight years. By 1987, average real weekly earnings had dropped to the level which prevailed in the early 1960s.[4] Because of relatively weak productivity growth, U.S. wages have had to rise more slowly than wages in many other developed countries. In 1970, U.S. wages were four and one-half times as high as Japanese wages. By now Japanese workers have almost caught up with American workers.

In addition to productivity growth, technological improvements are a major determinant of national competitiveness. Improvements in product quality or serviceability and product innovations are often the source of competitive success in international markets. For products that compete on such features, technological improvements in process or product design are significant influences on competitive outcomes.[5]

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[4] Economic Policy Institute, *The State of Working America* (October 1988).

[5] Improvements in product quality or serviceability and product innovations are especially important to competitive outcomes in high technology products, which account for about two-fifths of U.S. trade in manufactures.

Research and development drive the creation of new technology. In aggregate terms, the U.S. spends more on R&D than any other nation, but Japan and West Germany spend about the same fraction of their GNP on R&D and a much higher fraction on non-defense or commercial R&D (see Table 6). Approximately half of U.S. R&D spending is funded by the federal government. which spends the bulk of its money on defense and space programs.[6] Between 1980 and 1987, total federal R&D support increased 100 percent, but 90 percent of the increase went to the military. Real federal R&D spending for non-defense purposes in 1988 was 14 percent below its 1980 level.[7]

The problem of insufficient federal support for nondefense R&D is compounded by comparatively low U.S. corporate R&D spending. While R&D spending by U.S. firms has improved from the low levels of the late 1970s, the growth in spending by Japanese and German firms has been even faster (see Table 6).[8]

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[6] Military R&D programs can generate technological and knowledge spillovers for commercial uses, as the history of several American industries indicates. But times have changed. Several foreign governments are now sponsoring commercially oriented R&D programs in areas in which the U.S. government is focusing on narrow military applications. A recent study suggests that as defense needs in the U.S. have become more esoteric and highly specialized, the spinoffs of military R&D programs for the civilian economy have decreased. See Jay Stowsky, *Beating Our Plowshares with Double-Edged Swords*, Working Paper No. 17, Berkeley Roundtable on the International Economy, April 1986.

[7] About half of real federal R&D spending for nondefense purposes is concentrated in support for basic research in health sciences. Most of this spending goes to fund university research. See Martin Neil Baily and Alok Chakrabarti, *Innovation and the Productivity Crisis* (Washington, D.C.: The Brookings Institution, 1988).

[8] The leading firms in Japan's major industries now spend as much as or more than do their U.S. counterparts on R&D as a percentage of sales.

Some recent studies suggest that the problem in U.S. technological performance has not been as much the slowdown in the creation of new knowledge as the failure of industries to take advantage of available new technology.[9]

There are several possible explanations for the failure of U.S. firms to exploit technological opportunities as rapidly as their competitors. On the public policy side, there has been too little support, either in the form of public funding or tax policy, for "middle-ground" or generic R&D projects.[10] Such projects consist of applied research with commercial applications, but where the results are too general to make them attractive to private companies operating on their own. On the private side, R&D consortia among private actors to support such projects have been discouraged by antitrust considerations. The Justice Department under President Reagan significantly eased its antitrust restrictions on joint-venture R&D arrangements. The new regulations, however, still allow competitors excluded from a joint R&D venture to file damage suits and still limit the kinds of joint research activities exempted from usual antitrust conditions. Perhaps as a result, the U.S. has remarkably few private joint R&D ventures compared with the other advanced industrial countries at a time when the risk and capital requirements of new technologies preclude a go-it-alone R&D strategy by even the largest companies.[11]

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[9] See Baily and Chakrabarti, *op. cit.*, and Henry Ergas, "Does Technology Policy Matter?" in Bruce R. Guile and Harvey Brooks, eds., *Technology and Global Industry* (Washington, D.C.: National Academy Press, 1987).

[10] For a broader discussion of the lack of support for generic and middle-ground research, see Baily and Chakrabarti, *op. cit.*

[11] See Tom Jorde and David Teece, "Innovation, Strategic Alliances and Antitrust," paper prepared for Brookings Institution panel on microeconomics and growth, November 1988.

A major reason behind the failure of American firms to exploit technological opportunities is their relatively low investment rate in plant and equipment. New plant and equipment expenditures in manufacturing declined as a percentage of GNP in the 1980s (see Figure 1). As a result, the age of the nation's capital stock in manufacturing equipment has increased to relatively high levels by historical standards.

Capital investment also increases labor productivity. There is a strikingly close relationship between the rate of growth of the quantity of physical capital per worker and the rate of growth of labor productivity among the advanced industrial countries (see Figure 2).[12] During the 1970-86 period, the U.S. consistently had the lowest investment rate in plant and equipment, the lowest growth in physical capital per worker, and the lowest growth in labor productivity (see Table 7). Furthermore, the already low U.S. investment rate has been on a downward trend—the net national investment rate in the 1980s was lower than during the 1950s, 1960s and 1970s (see Figure 3).

As the preceding discussion indicates, public or private actions that reduce the trade imbalance; increase productivity growth; generate high-wage, high-productivity jobs; stimulate more R&D spending; hasten the diffusion of technological knowledge; and increase the rate of capital formation, can improve the nation's competitiveness. The next section considers policy actions required to realize these objectives.

Before considering these actions, it is important to emphasize that foreign-owned firms operating in the U.S. can contribute to national competitiveness in all of the ways identified here. Foreign-owned firms can invest in physical and human capital and R&D; create high-wage, high-productivity jobs; introduce new production technologies and organization skills; and increase U.S. exports and reduce U.S. imports, thereby improving the trade balance. The basic challenge for government is to formulate policies that will encourage both domestic and foreign firms to take the private actions required to strengthen national competitiveness.

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[12] George Hatsopoulos, Paul Krugman, and Lawrence Summers, "Beyond the Trade Deficit," unpublished paper, April 1988.

IV. GENERAL POLICIES TO IMPROVE U.S. COMPETITIVENESS

This section suggests policy initiatives to strengthen national competitiveness over the long run. The policy recommendations include: a gradual deficit reduction plan; changes in government spending priorities and tax policy to increase national saving and national investment in physical plant, human and knowledge capital; the further relaxation of antitrust laws and the use of government funds to stimulate R&D consortia for generic or middle-ground technologies; and the use of international negotiations and national trade laws, including the new Omnibus Trade Bill of 1988, to maintain open and fair conditions in global trade. The following discussion describes the rationales for each of these recommendations.

The first step in addressing the nation's competitiveness is increasing its investment commitment. This is where the nation's macroeconomic challenge and its competitiveness challenge come together. During the next several years, the gap between national saving and national investment must be reduced in ways that encourage more investment. This will require an increase in national saving.

The U.S. saved less than two percent of its income in 1986 and 1987. This is less than one-third of the savings rate realized in the 1970s, less than one-fifth of the average saving rate of the major industrialized countries, and only one-eighth of the saving rate in Japan.[13]

Low national saving discourages national investment by raising the cost of capital. Recent studies suggest that the cost of capital is significantly higher in the United States than in Japan. For example, one study indicates that in 1985, American firms had a real cost of funds of six percent while Japanese firms had a real cost of funds of only 1.5 percent.[14]

Although there is disagreement about the exact size of the cost of capital disadvantage to American firms, there is general agreement that such a disadvantage exists and that the real cost of capital in the U.S. remains high by historical standards. The high cost of capital is an important factor behind the myopia that is thought to affect American companies.[15] The cost of funds plays a critical role in determining how much a firm values future as opposed to current earnings.[16] It influences how much patience is actually rational. Because American companies have operated in an environment of high capital costs, they have rationally developed a short-term focus.[17]

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[13] Rudiger Dornbusch, James Potreba, and Lawrence Summers, "Business, Economics and the Oval Office: Advice to the New President and Other CEOs," *Harvard Business Review* (November 1988).

[14] George N. Hatsopoulos and S.H. Brooks, "The Cost of Capital in the United States and Japan," paper presented at the International Conference on the Cost of Capital, Kennedy School of Government, Harvard University, 1987.

[15] See Dornbusch, Potreba, and Summers; Martin Feldstein, "Business, Economics and Oval Office: Advice to the New President and Other CEOs," *Harvard Business Review* (November 1988).

[16] For example, an investment decision that lowers a firm's earnings by one dollar today while increasing earnings by two dollars ten years from now is a profitable decision if the firm's cost of funds is five percent, but it is an unprofitable decision if the firm's cost of funds is ten percent. It follows that a firm's investments will be rationally lower, the higher the cost of funds it faces. See Hatsopoulos, Krugman and Summers, *op. cit.*

The low national saving rate also makes the nation dependent on foreign capital inflows to finance its productive investment. Perhaps as much as two-thirds of gross private investment in plant and equipment is currently financed by foreign funds. There can be no significant reduction in the nation's current account imbalance without a reduction in its reliance on foreign capital.

Although *private* saving has also fallen in the 1980s below its post-war average, record federal budget deficits in the 1980s have been the major cause of low *national* saving. The deficit has absorbed more than two-thirds of the nation's private savings during the past five years, drawing funds away from private investment and making the nation increasingly dependent on foreign investment to make up the difference. As a result, the deficit has been a major burden on the nation's competitiveness.

There is widespread concern that the deficit will not go away as a result of continued economic growth. Indeed, recent estimates by the Congressional Budget Office show the deficit beginning to rise even though the economy is rapidly approaching full employment.[18] Therefore, the first and most significant step toward improving the nation's competitiveness is a credible program to reduce the deficit. Meaningful deficit reduction will require real policy changes on both the revenue and spending sides of the ledger.

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[17] The myopia of American business has also been encouraged by the cyclical variability and relatively low growth rate of the American economy relative to that of Japan. Japan has had only one serious recessionary downturn during the postwar period. Japan's producers have come to expect rapidly growing national markets with little perceived risk of a slowdown which could reduce returns on investment. In contrast, American producers operate in a national market which has grown slowly and which has suffered from recurrent and sometimes prolonged recessionary slowdowns. This has increased the riskiness of investment for American companies and has encouraged a short-term focus.

Since this is not a report on deficit reduction, we will not make any detailed recommendations for the necessary changes. But we do endorse the need for a sustained deficit reduction package to increase national saving and investment. The goal of deficit reduction should be to bring the budget into approximate balance by fiscal year 1993 in accordance with the Gramm-Rudman guidelines. But the spending and revenue measures used to realize this goal must be guided by the additional goal of restoring national competitiveness. And this implies that the deficit reduction package finally adopted have certain features.

On the spending side, federal priorities must be changed. In particular, the composition of federal spending must be shifted toward spending in certain critical public investment areas including education, worker training, infrastructure, and commercial science and technology. We must address the glaring weaknesses in the nation's primary and secondary education; shortages in the number of qualified engineers and scientists; the erosion in the laboratory and research facilities of the nation's universities;[19] the deterioration of the national infrastructure and its negative consequences for the productivity performance of the private sector;[20] and the relative decline in the nation's commitment to commercial R&D spending compared to many other industrial countries.

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[18] The Congressional Budget Office predicts that the deficit will rise to $220 billion by fiscal year 1993. Only if the Social Security Trust Fund surplus is included does the deficit appear to be on a downward trend.

[19] Federal funding for university plant and facilities for research has declined over 92 percent in real terms over the past twenty

There is a consensus among business, educational and civic leaders that the most important spending priority for national competitiveness in the coming years is education. As a result of new production technologies, the skill requirements of new jobs are projected to rise rapidly over the next decade.[21] At the same time, the labor force is projected to grow much more slowly than in the 1980s, and more than one-half of new workforce entrants will come from groups which have historically experienced high dropout and illiteracy rates and low educational achievement rates relative to the rest of the population. The nation faces a developing shortage in the skilled workforce it needs to be a competitive location for production by domestic and foreign firms alike. The nation also suffers from a shortage in engineering and scientific manpower—thousands of engineering faculty jobs around the country are currently unfilled, jeopardizing both engineering training and research.

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years. Corporate and university leaders agree that many of these facilities are far behind the technological frontier, impeding the pace of university basic research and the training of engineers and scientists for the corporate sector.

[20] A recent study by the Federal Reserve Bank of Chicago shows a strong correlation between productivity performance in the private sector and investment in public infrastructure, including roads, transportation facilities, and waste management. See David Alan Aschauer, "Net Private Investment and Public Expenditure in the United States, 1953-84," Occasional Paper, Federal Reserve Bank of Chicago, 1987.

[21] These projections are reached by William Johnston and Arnold Packer in their study for the Hudson Institute, *Workforce 2000: Work and Workers for the 21st Century* (1987).

Although education is largely a state issue, federal programs are necessary to address certain important needs. Along with (rather than at the expense of) deficit reduction, federal government spending should be gradually increased on several fronts including: educational programs serving the disadvantaged,[22] and loan and grant programs to ensure access to post-secondary education; programs to strengthen math and science education—areas in which the U.S. lags behind its major competitors,[23] and which are needed if the nation is to increase its supply of qualified engineers; and training programs for dislocated workers. Most of the necessary programs to serve these objectives currently exist, but, due to budgetary priorities none of them are fully funded to serve the eligible populations.

On the revenue side of the ledger, the deficit reduction package must be sensitive to the effects of tax policy on private saving, and on investment and R&D by private companies.

The federal government does not bear sole responsibility for the low national saving rate. The private saving rate, which was already low throughout the 1960s and 1970s compared to the private rates of other industrial countries, fell to even lower levels in the 1980s.

The causes of the traditionally low private saving rate and its more recent decline are not well understood. Nonetheless, many believe that the federal tax code—

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[22] The federal government already has in place several successful programs to help the economically disadvantaged at primary and secondary school levels, including the Women, Infants and Children Program, the Head Start Program, and Chapter I of the Education Consolidation and Improvement Act. All of these programs have been severely underfunded and have served only a small fraction of eligible populations.

[23] The National Science Foundation is committed to strengthening engineering and scientific training at the post-secondary level out of its larger budget, which is currently slated to double by 1993.

which treats saving unfavorably—has been a factor, and that changes in the tax code to encourage higher levels of private saving are warranted. Some possible measures in this direction include a broad-based consumption tax, limiting home-equity loan deductions, phasing out deductibility of mortgage interest on vacation homes, and expanding the eligibility for IRAs. Further analysis of the relationship between private saving and taxation is needed before specific moves are made in any of these directions.

As far as investment spending is concerned, the 1986 Tax Reform Act, while introducing several improvements in the nation's tax system, reduced the incentive for investment in new equipment. The corporate tax rate, which applies primarily to profits earned on past investment, was reduced, resulting in a windfall on the returns to the existing capital stock. In contrast, the investment tax credit, which applies only to new investment, was eliminated, reducing the anticipated returns from new investment. Together, these two tax changes raised manufacturing production costs and tended to reduce demand for manufacturing output, particularly in high-technology industries.[24]

A pro-competitiveness deficit reduction effort should consider possible changes in the tax code to increase the incentives for private investment. Restoring the investment tax credit, a proven measure for stimulating investment in plant and equipment, is likely to be at odds with deficit reduction as long as no new taxes are introduced. But, as a group of distinguished economists has recently recommended, it may be possible to regain much of the credit's incentive effect at a fraction of its former cost by adopting an incremental approach.[25] An incremental tax credit would apply only to the change in a company's net capital stock during two successive years. Thus, it would subsidize expansion of the net stock of plant and equipment, but provide no subsidy on the existing capital stock.

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[24] See Dornbusch, Potreba, and Summers, *op. cit.*

[25] Dornbusch, Potreba, and Summers, *op. cit.*

In addition to the re-introduction of some form of investment tax credit, the tax treatment of capital gains should be reconsidered. In particular, to encourage long-term investment, the taxation of capital gains could be steeply graduated, declining from the current high rate on short-term gains to a zero rate on gains earned over a five to ten year period.

Finally, as a stimulus to private investment in knowledge capital, a permanent tax credit for corporate R&D should be considered. A conservative estimate indicates that the 1981-85 R&D tax credit increased corporate R&D by 1.2 percent or $500-$600 million per year.[26] And a recent study suggests that the actual effect may have been much larger—increasing corporate R&D spending by as much as $2.9 billion per year between 1982 and 1985.[27] Whatever the actual size of the effect, the overall case for an R&D tax credit is compelling. Study after study indicates that the social return from corporate R&D is two to four times the private return. The nation should use tax policy to encourage private R&D spending which generates significant returns throughout the economy.

In addition to tax policy, government policy should be used to encourage private coalitions or consortia for middle-ground or generic R&D. It is the nature of such R&D that the results are likely to benefit a large number of producers, no one of which is likely to be willing to finance the R&D commitment to generate these benefits for others. Under these circumstances, there is a real possibility that a partnership among private actors or between them and the public sector can work to the advantage of the nation.

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[26] For a summary of the conservative estimates of the effects of the R&D tax credit on R&D spending see *Research and Experimentation Tax Credit*, Hearings before the Subcommittee on Oversight of the House Committee on Ways and Means, 98th Congress, 2nd Session, August 2-3, 1984.

[27] Baily and Chakrabarti, *op. cit.*, p. 129.

Public-private consortia can be an effective means for stimulating and organizing generic research projects. Private actors, responding to market conditions and evolving technological and scientific knowledge, identify promising directions for generic R&D, and the government provides an infusion of public funds to encourage the commitment of private resources. Sematech, a recently formed consortium for research in semiconductor manufacturing processes, is an example of such a public-private consortium. The new federal initiative on superconductivity calls for the establishment of similar cooperative research groups for basic research in superconductivity.

Public-private R&D consortia for competitiveness should have seven distinguishing characteristics.[28]

- First, they should involve risky but promising applied R&D activities at a pre-competitive or generic stage.
- Second, the identification of potential activities should come from the private sector, not from the government. The government should follow the lead of the private sector and not engage in picking "winning" technologies itself.
- Third, the consortia should be financed partly by private firms expecting to benefit from the results

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[28] The characteristics of public-private R&D consortia discussed in this Report are based on suggestions in Baily And Chakrabarti, *op. cit.*, and Laura D'Andrea Tyson, "Business, Economics and the Oval Office: Advice to the New President and Other CEOs," *Harvard Business* (November 1988).

of the R&D effort and partly by the government. Because of the difficulty companies will have in earning an adequate rate of return on generic R&D which generates knowledge for other companies, it is appropriate to provide part of the cost with public funds. But because of the danger of wasteful government projects, it is appropriate to insist that most of the funding be private.

- Fourth, consortia should be organized cooperatively to encourage collaboration and communication among private producers. Company scientists should perform the R&D and cooperatively decide how to proceed.
- Fifth, these consortia should have a commercial orientation, not a military one. In current technological and competitive circumstances, the U.S. should no longer rely on uncertain and costly spillovers from military R&D to substitute for applied, commercially focused R&D. While devoting significant R&D support to the semiconductor industry for defense purposes, the U.S. found itself increasingly dependent on commercially developed semiconductor technology from Japan for its defense needs. If anything, the recent evidence from the semiconductor industry suggests that the beneficial spillovers from commercial R&D to defense uses may be at least as great as the beneficial spillovers from defense R&D to commercial uses.
- Sixth, participation should be based on contributions to the United States' economy such as; R&D in the United States, the participants' added value in the United States, and potential for exploitation of the results of the R&D in the United States.
- Seventh, and finally, the government should further relax antitrust laws to encourage the formation of joint R&D ventures among private firms.

> As a result of the National Cooperative Research Act of 1984, antitrust restrictions on joint-venture R&D arrangements have been eased. The 1984 regulations, however, still allow competitors excluded from a joint venture to file damage suits, although only single rather than treble damages are permitted. While the elimination of treble damages is an important step forward, cooperating firms are still not protected from antitrust litigation.[29] In addition, the antitrust relaxation in the 1984 law is limited to joint research activities and does not apply to joint development and production arrangements often required for the successful commercialization of new technology. For example, the Act's limitation to joint marketing of intellectual property unwisely precludes joint manufacturing and production of innovative products and processes which in turn may provide the cooperating firms with significant feedback information to aid in further innovation and product development.

As a result of these limitations in the 1984 antitrust legislation, there is still a great deal of antitrust uncertainty facing firms considering formation of research consortia. In addition, the realization of commercial returns from such cooperative efforts may be impeded by the remaining restrictions on related joint production activities. Perhaps as a result, the U.S. has remarkably few private joint research ventures compared to the other advanced countries at a time when the risk and capital requirements of new technologies increasingly preclude a go-it-alone strategy by even the largest companies.

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[29] The cost of defending an antitrust suit can be extremely high, which is not alleviated by the Act's exceedingly narrow award of attorney's fees to prevailing defendants.

During this session of Congress, a revision to the National Cooperative Research Act will be introduced which attempts to address some of the substantive and procedural shortcomings of the existing law.[30] There are two basic principles behind this amendment: first, the National Cooperative Research Act should be extended to encompass joint production as well as joint research acticities under certain circumstances; and second, procedures should be adopted that remove the threat of damages for cooperating firms that secure approval for their cooperative arrangements from the Department of Justice and other relevant government agencies.

Finally, in addition to the other policy measures discussed here, the government must make active use of international negotiation and domestic trade policy to maintain and expand an open global trading system. The U.S. needs a world of expanding markets to eliminate its current account deficit. The drop in the dollar's value gives producers operating in the U.S. an opportunity to capture a growing share of such markets. Achieving such an outcome will require a tough American negotiating stance in the Uruguay Round talks and enforcement of the nation's new trade law to open foreign markets and to insure fair competition in both U.S. and international markets.

V. RECAP OF PRO-COMPETITIVENESS POLICY RECOMMENDATIONS

The nation has an opportunity to use the enhanced competitiveness afforded by a lower dollar to build the foundation for improved competitiveness over the long run. To realize this objective, six main policy initiatives are recommended: first, the introduction of a gradual deficit reduction package to bring the budget to approximate balance by 1993; second, a change in the composition of federal spending toward education, worker retraining, science and technology, and infrastructure; third, changes in tax policy to encourage greater private saving and more private investment and R&D spending; fourth, the use of government research funds to support private-public consortia for middle-ground or generic R&D in areas judged to be of significant market and technological value by the private sector; fifth, the further relaxation of antitrust restrictions on private cooperative R&D consortia; and sixth, the active use of national and international trade laws and negotiations to insure fair competition in both U.S. and international markets.

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[30] A copy of one such draft that will be introduced shortly by Reps. Rick Boucher (D-VA) and Tom Campbell (R-CA) is attached as an appendix to this Report (Appendix A).

VI. THE ROLE OF ELECTRONICS IN U.S. COMPETITIVENESS

So far this Report has taken a broad, economy-wide perspective. Trends in national competitiveness, broadly defined, have been examined, and recommendations for economy-wide or macroeconomic policies to improve long-run competitiveness have been made. The discussion has been based on the notion that competitiveness is an economy-wide concept that is logically distinct from the competitive position of private producers in particular industries.

Such a perspective overlooks the possibility that certain industries or activities may contribute more than others to national competitiveness over the long run. Yet it is just such a possibility that has motivated growing national concern about the health of the U.S. semiconductor industry and that is a factor behind growing concern about U.S. participation in HDTV. To evaluate these concerns and the policy recommendations that accompany them, this section of the Report examines some of the reasons why the electronics sector—broadly defined to include the semiconductor industry, the computer industry, the display industry, the telecommunications industry, and various segments of the consumer electronics industry—is judged by many to be of particular importance to national competitiveness.

From a national competitiveness perspective, the critical node of the electronics sector is the microelectronics or semiconductor industry. Semiconductors are at the heart of electronics products ranging from computers, telecommunications systems, and industrial robots to VCRs, video games and state-of-the-art television receivers. More fundamentally, semiconductors are a major source of innovation in products and processes throughout the economy.

The spillover effects of the microelectronics revolution on the rest of the economy are best understood by distinguishing between two categories of effects: linkage impacts and technological spillovers.[31] Linkage impacts are those that generate increasing positive benefits for economic activities tied to chip production. Technological spillovers are pervasive, benefit-creating impacts on scientific and technological activities more loosely associated with chip development and production—for example R&D in physics or superconductivity.

The sustained economic benefits from linkage impacts arise because chip production generates a cycle in which increased investment in R&D and capacity leads to increasing chip performance at decreasing cost. The improved price-performance characteristics in turn deliver improved price-performance in products like computers, and also generate new markets such as antiskid braking systems. The applications generate broad societal returns. As these markets expand, substantially increased demand for chips is generated. Increased user demand occasions expanding investment in chip development and production, which leads to another round of improved price-performance. The cycle is repeated. Such has been the history of the microelectronics industry for over three decades.

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[31] The following discussion is from Michael Borrus, *Competing for Control: America's Stake in Microelectronics* (Cambridge, MA: Ballinger, 1988).

Although somewhat imprecise by contrast to linkage impacts, technological spillovers generally result from the interdependence that characterizes precursor and complementary technological activities. This is most obvious in the relationship between chips and the systems that incorporate them. Increasingly, the chips embody the systems functions and performance characteristics of the products that incorporate them: advanced chips are systems and innovation in systems occurs at the level of the chip. This is the most precise type of technological spillover but there are other, broader, spillovers as well.

Advances in chip technology depend upon and contribute to continued technological innovation in physics, chemistry and materials sciences. For example, it is no coincidence that recent advances in superconducting materials originated partly at IBM Research, AT&T Bell Laboratories, and Bellcore where the search for superfast microelectronic switching devices for computer and telecommunications applications motivated experimentation with superconductivity. The gains from superconductivity will not be confined to chips but will pervasively influence activities ranging from electricity generation to high-speed transportation.

As a result of both linkage effects and technological spillovers, microelectronics has driven both product and process innovation throughout the economy. Microelectronics-based technologies are already automating both primary commodity and goods production and transforming the activities that make up the service industry. Global competition in a variety of both traditional industries, such as textiles and steel, and high-technology industries, such as aircraft, is increasingly based on microelectronic-driven innovations.

In addition to their effects on innovation and competitiveness in a wide variety of industries, the microelectronics industry and the electronics sector, more broadly defined, are important to national competitiveness in more direct ways. Between 1965 and 1985, the global output of the electronics complex grew by over 13 percent per annum in real terms, and by 1985 it equalled the global output of the automobile industry and surpassed the global output of the steel industry. In 1987, U.S. sales of electronics products exceeded one-quarter of total durable industries' shipments and have been growing at over five percent annually. Electronics, in total, employs more than one and one-half million Americans, many of them highly skilled. The wage of the average worker in the electronics industries is higher than the average wage of workers of similar skill, education, experience, and personal characteristics, such as age, sex, and race, in many other manufacturing activities and in most service activities.[32]

The electronics sector is tightly linked to many other portions of the U.S. economy. Not only do the nation's defense industries depend on electronic technologies but both manufacturing and service industries—ranging from the production of numerically controlled machine tools to banking and insurance—use electronic products both directly and indirectly. These products—which range from CB radios to satellite-based communications systems, carbon resistors to vastly powerful computers—are probably distributed more widely through the rest of the U.S. economy than the output of any other industry.[33] Because many electronics products serve as inputs in other sectors of the economy and because they are produced under conditions of increasing returns or declining costs due to the significant learning curve economies realized in their production, the electronics sector gives rise to what economists call "linkage externalities"—increasing private returns in the electronics industry are accompanied by increasing societal returns in downstream user industries.

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[32] This conclusion is based on calculations in Williams Dickens and Kevin Lang, "Why It Matters What We Trade," in Laura D'Andrea Tyson, William Dickens, and John Zysman, eds., *The Dynamics of Trade and Employment* (Cambridge, MA: Ballinger, 1988).

Finally, as the global electronics industry has grown, it has become an increasingly important determinant of national trade flows and national trade balances. The U.S. trade position in electronics deteriorated between 1980 and 1987, although measures of the extent of the decline vary depending on how broadly electronics is defined (see Table 8 and Figure 4).[34] All of the estimates indicate that the decline was broad-based, ranging from consumer electronics and components to office computing equipment and sophisticated telecommunications equipment. Notably, the electronics trade balance continued to drop despite the dollar's decline. Even with further declines in the dollar's value, the U.S. will continue to run a significant deficit in many electronic products. This is true for many consumer electronics items. To illustrate, about 13.3 million VCRs were sold in the U.S. in 1987. Only 230,000 were made in the U.S. (assembled from imported parts), resulting in a total import bill of over $3 billion. Although by 1989, nearly 900,000 VCRs are expected to be made in the

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[33] Office of Technology Assessment, *International Competitiveness in Electronics* (Washington, D.C.: USGPO, November 1983).

[34] It is important to emphasize that the electronics trade balance is heavily influenced by the decisions of U.S. multinationals. Some estimates indicate that as much as a third of the electronics imports from individual East Asian countries come from U.S.-owned operations.

U.S., they will represent approximately seven percent of estimated sales, and will likely rely heavily on imported components, implying a continued large deficit in this item for the foreseeable future.[35]

World production shares in electronics also indicate a drop in U.S. competitiveness relative to other regions. According to an analysis of data collected by the Electronic Industries Association of Japan (EIAJ), the U.S. production share of electronics dropped from 50.4 percent in 1984 to 39.7 percent in 1987. During the same period, Japan's share rose from 21.3 to 27.1 percent. The same trend was observed in a different study, with sligthly different numbers, done by the European Electronics Industry Council.[36]

World production shares in semiconductors also indicate a drop in U.S. competitiveness in the last decade, particularly relative to Japan. Figures from Dataquest indicate that Japan produced slightly more than 50 percent of world production in 1988 while the U.S. produced around 37 percent. In 1978, the U.S. accounted for 55 percent and Japan less than 30 percent of world production.[37]

The next section attempts to demonstrate that an enhanced U.S. participation in consumer electronics with HDTV products in the future can make a limited contribution to maintaining U.S. competitiveness in electronics. The increasing sophistication of consumer electronics technology embodied in HDTV products will mean that there may be more spinoffs to the rest of the electronics industry from consumer products research and production. Even more important could be the relationship between the diffusion of HDTV and the building of the national telecommunications network.

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[35] Allen Lenz, "Slimming the U.S. Trade and Current Account Deficits," *The AMEX Review, Special Papers*, No. 16 (October 1988).

[36] Lawrence M. Fisher, "U.S. Share Declines in Electronics," *New Times*, (January 5, 1989), p. C1.

[37] "Preliminary 1988 Worldwide Semiconductor Market Shares: Japanese Gain Share: Memories and Micros Dominate Market," *Dataquest Newsletter*, January 1989, pp. 1 and 3.

VII. THE ROLE OF CONSUMER ELECTRONICS WITHIN THE ELECTRONICS COMPLEX

There are three important forms of linkage between the consumer electronics industry and the rest of the electronics complex. They are:

- upstream effects
- downstream effects
- manufacturing effects

Upstream effects derive mainly from the role of consumer electronics production as a source of demand for inputs, and, in particular, for semiconductor components. The consumer electronics industry in the United States first contracted and then shifted from domestic to predominantly foreign ownership. The ability and interest of U.S.-based semiconductor firms to service markets for consumer-related semiconductors virtually disappeared.[38] By the mid-1980s, only six percent of semiconductor production in the U.S. went to consumer applications, whereas in Japan, 40 percent did. In dollar terms, this meant that Japan was producing 7.2 billion consumer chips in 1987 while the U.S. produced only 0.9 billion. The corresponding figure for Europe was around four billion.[39]

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[38] It should be noted that the decision of U.S. semiconductor firms to stop building chips for consumer electronics at the beginning of the massive growth in imports of consumer products occurred much earlier than the acquisition of major U.S. consumer firms by foreign firms.

[39] Statement by Jeffrey A. Hart submitted to the Subcommittee on Telecommunications of the House Committee on Energy and Commerce, September 7, 1988, p. 8.

There is an honest dispute about how this occurred. Some U.S. firms claim that foreign-owned consumer electronics firms had preferential supply arrangements that excluded them from the market. The more vertically-integrated foreign electronics firms often sourced their semiconductors from their internal semiconductor divisions. In all the major industrialized regions, there is a preference for working with regional suppliers of components whenever possible. The Japanese consumer industry, as represented by the EIAJ, claims that U.S. firms were unable to produce the necessary products, or to deliver them on time, or to match the quality/reliability of other (particularly Japanese) producers. The U.S. semiconductor firms accuse the Japanese of preferentially sourcing from Japanese semiconductor producers. Both of these claims may be true. Of key importance for many U.S. firms was the fact that the consumer chip business was less profitable, because it involved standard devices in which markets were highly competitive, than business for industrial or defense applications.

Another key factor was the increased product design activity that built up in Japan. Product design in a foreign country makes it extremely difficult for U.S. semiconductor firms to compete. It is estimated that around 12% of the semiconductors produced in Japan are used in VCRs. The end result of these two factors was major abandonment of consumer chip production in the U.S. This is particularly true in such specialty devices as charge-coupled devices (CCD) and liquid crystal displays (LCD).

Downstream effects refer to the impact of consumer electronics on industries downstream from the semiconductor industry. The VCR volume base led to video cameras. The camera base contributed to commercially priced CCD chips. The VCR, camera and CCD base led to camcorders, still video photography, video printers and new video printer film.

In a similar manner, Japanese strengths in LCDs for watches and calculators helped to give them an edge in the emerging markets for laptop computers and personal TVs.

Manufacturing effects involve the loss of strength in generic manufacturing skills and technologies associated with the reduced role of U.S.-owned firms in the consumer electronics industry. While a number of U.S. firms were able to match their international competitors in the adoption of advanced manufacturing techniques, such as automated insertion and surface-mount technologies, the majority failed to do this rapidly enough to meet the competition. These technologies are important not just for consumer electronics but for many other kinds of high-volume production. The decline of the U.S. consumer electronics industry, therefore, meant a narrowing of the manufacturing skill base of the U.S. economy.

There are reasons to believe that upstream, downstream, and manufacturing effects will be even greater in the next two decades than they were in the past.[40] HDTV circuitry will be much more complex than NTSC circuitry. HDTV circuitry needs could contribute to advancing technology in some important areas, such as digital signal and image processing, and parallel processing. HDTV receivers will require larger and better video frame storage devices than NTSC receivers. In addition. competition in the HDTV business will create sizeable incentives for the development of large displays, and particularly for the development of flat-panel displays—e.g., liquid crystal displays (LCD), and semiconductor-based projection systems.

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[40] Competitive issues are also raised by the efficient use of the broadcast spectrum. To the extent the Federal Communications Commission allocates spectrum efficiently, new opportunities for growth in the U.S.-based land mobile and cellular telephone industry will be created. An important issue in the development of HDTV is the bandwidth proposed for each channel and the channel spacing. The EIA believes that the FCC should consider spectrum efficiency and HDTV terrestrial signal quality required to be competitive with other delivery media when it adopts the Terrestrial HDTV transmission standard.

The downstream spillover effects of HDTV technology could be significant in the computer, defense electronics, and telecommunications industries. The problems of image and digital signal processing that have to be solved for HDTV receivers also have to be solved for fast displays of color images on advanced computer workstations. The production of large, high-resolution displays for HDTV equipment will allow some firms to produce cheaper and more competitive displays for computers and workstations.

There is an important mutually reinforcing relationship between advances in HDTV and network (telecommunications) technology. The networking of advanced computer workstations creates network architecture design problems similar to those posed by the use of HDTV receivers as interactive terminals. Interactive video and interactive 3-D color CAD/CAM are both more demanding than existing interactive character and graphics networking.[14] If you can solve one problem, then you have more or less contributed to the solution of the other. The unanswered question in this equation is how much demand there will be for "interactive" (two-way) as opposed to "passive" (one-way) television.

More important than the technological linkages between HDTV and telecommunications are the likely linkages between the two that arise with the building of a new national telecommunications infrastructure based on optical fibers. HDTV signals will be delivered to the home before the fiber optic network is universally operational. Nevertheless, the sooner HDTV broadcasts and other home deliveries begin, the sooner there will be demand for transmitting HDTV signals via optical fiber (because of the greater fiber optic bandwidth and the opportunity for reducing transmission noise with broadband digital signals). By the same token, the faster high quality fiber optic delivery to the home is in place, the easier it will be to convince consumers to make the switch from NTSC, or interim products, to HDTV.[42]

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[14] Workstation firms are now introducing NTSC video image processing in the high-end of their product lines.

The greater U.S. participation in HDTV consumer markets is, therefore, the greater the upstream, downstream and maunfacturing benefits for the rest of the U.S. economy will be. Thus, policy measures should be aimed at maximizing U.S. participation. Because U.S. based foreign-owned firms already possess such an important stake in this country's R&D and manufacturing of consumer electronics, they should be included in efforts to promote the HDTV industry.[43]

VIII. THE POTENTIAL IMPORTANCE OF HDTV TO CONSUMER ELECTRONICS

Factory sales of consumer electronics products were around 30 billion dollars in 1987. Of this total, 42 percent was derived from sales of TVs, VCRs, and camcorders (see Table 9 below). Over twenty million color TV sets, 11.6 million VCRs, and 1.6 million camcorders were sold in the United States in 1987.

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[42] For further information on this point, see Appendix C prepared by the Fiber Optics Division of the Telecommunications Industry Association.

[43] Joseph Donahue, of Thomson Consumer Electronics in Indianapolis, estimates that the annual R&D expenditures of Thomson, Zenith, and Philips in the United States are around 150 million dollars per year.

TABLE 9

Factory Sales of Consumer Electronics Products
in the United States, 1977-1988,
in millions of dollars, including imports

Year	Mono TVs	Color TVs	Proj. TVs	VCRs	Video Disc	Audio Systems	Audio Comp.
1977	530	3289		180		606	1275
1978	549	3674		326		748	1143
1979	561	3685		389		748	1178
1980	588	4210		621		809	1424
1981	505	4349	287	1127	55	720	1363
1982	507	4253	236	1303	54	573	1181
1983	465	5002	268	2162	81	630	1268
1984	419	5538	385	3585	45	976	913
1985	309	5562	488	4738	23	1372	1132
1986	328	6024	529	5258	26	1370	1358
1987	287	6271	527	5093	30	1048	1715
1988e	200	6530	525	5055	40	1140	1800

Source: EIA, *1987 Electronic Market Data Book*, p. 6; EIA, *Consumer Electronics U.S. Sales*, January 1989.
e = estimate

Several of the largest U.S.-owned firms in consumer electronics were purchased by foreign firms. RCA was purchased first by General Electric in 1985, and then sold to Thomson of France in 1987. Philips of the Netherlands purchased Magnavox in 1975, and Philco and Sylvania in 1981. Zenith remains the only major U.S.-owned producer of TVs. In 1987, Thomson, Zenith, and Philips were the "big three" firms and accounted for about half of all color TVs sold in the United States. The rest of the market was divided among mostly Japanese and Korean producers. Both U.S.-owned and foreign-owned firms contribute to U.S. competitiveness in a variety of ways. There is significant variance in the degree to which each firm locates its research and development, manufacturing, and component production/sourcing in the United States (see Tables 10-11).

Despite the increased participation of foreign-owned firms in the United States, the color TV part of the consumer electronics market still retains a significant proportion of local content. The domestic manufacturing content of the average color TV made in the United States in 1987 is estimated to be around 70 percent,[44] and there has been a reversal in the last year or so of the downward trend in domestic content thanks to increased use of picture tubes manufactured in the United States. A number of foreign-owned tube manufacturing facilities came on line, a development which owes much to the decline in the value of the dollar relative to Asian and European currencies (see Table 10 and Figure 5). The foreign content of TV sets is primarily in the electronic circuitry, but there is also some foreign content in the form of license and royalty payments for tube and chassis technology.

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[44] This estimate is based on figures for U.S. content of color TV receivers manufactured by Thomson. In Thomson's case, the U.S. content was 74 percent for 20 inch direct view receivers, 77 percent for 26 inch direct view receivers, and will be 82 percent for 31 inch direct view receivers. U.S. content increases in sets with the larger pictures because the tubes are mostly manufactured in the United States and they become a larger proportion of the total manufacturing cost of the larger sets. The domestic content of receivers produced by other firms may be somewhat lower than Thomson, but 70 percent is a reasonable estimate given the practices of other firms.

U.S. Set and Tube Production, 1988

TABLE 10

Company	Location	No. of U.S. Employees	Plant Type	Annual Production	Export/Where?
BANG & OLUFSEN (Joint Venture w/Hitachi)	Compton, CA (opening 1989)	(See Hitachi Below)	Assembly	Not available	yes/Canada
GOLDSTAR	Huntsville, AL	400	Total Production	1 million	yes/Taiwan
HARVEY INDUSTRIES	Athens, TX	900	Cabinet Assembly/TV Assembly	600,000 capacity	yes/Mexico, Far East
HITACHI	Anaheim, CA	900	Total Production for 24", 27" 31"	over 360,000	no
JVC	Elmwood Park, NJ	100	Total	480,000	yes/Canada
MATSUSHITA	Franklin Park, IL	800	Assembly	1 million capacity	yes/Japan
AMERICAN KOTOBUKI (Subsidiary of Matsushita)	Vancouver, WA	200	VCR/TV Assembly	Not available	Not available
MATSUSHITA (Joint Venture w/Philips)	Troy, OH (opening spring 1989)	100-200 upon opening; eventually 400	Tubes	1 million	Not available

MITSUBISHI	Santa Ana, CA	550	Final Assembly	400,000	no
MITSUBISHI	Braselton, GA	300	Total/Full	285,000	no
NEC	McDonnough, GA	400	Final Assembly	240,000	no
O-I/NEG TV PRODUCTS (Joint venture of Owens-Illinois & Nippon Electric Glass)	Columbus, OH	800	Tubes (capabilities up to 45")	Not available	no
O-I/NEG TV PRODUCTS	Pittston, PA	750	Tubes (capabilities up to 45")	Not available	no
O-I/NEG TV PRODUCTS	Perrysburg, OH	75	Component glass for TV (solder glass)	Not available	no
ORION	Princeton, IN	250	Assembly	Not available	yes
PHILIPS	Arden, NC	400-500	Parts (Plastic Cabinets and Accessories)	Not applicable	yes/Mexico, Canada
PHILIPS	Greenville, TN	3,200	Assembly/Full Manufacturing	over 2 million	yes/Canada, Taiwan & Mexico
PHILIPS	Jefferson City, TN	1,000	Parts (Wood Cabinets)	6-700,000	no

TABLE 10—Continued

Company	Location	No. of U.S. Employees	Plant Type	Annual Production	Export/Where?
PHILIPS	Ottawa, OH & Emporium, PA	2,300	Tubes	3 million	no
SAMSUNG	Saddlebrook, NJ	250	Production for 13"-26" TVs	1 million capacity	yes/Canada
SANYO	Forrest City, AR	400	Assembly	1 million capacity	no
SHARP	Memphis, TN	770	Assembly	1.1 million	no
SONY	San Diego, CA	1,500	Full Manufacturing of Color TVs & Tubes	1 million	yes/Canada, South America, Central America, Taiwan & Japan
TATUNG	Long Beach, CA	130	Assembly	17,500	yes/Canada, Mexico & Taiwan
THOMSON	Bloomington, IN	1766	Full Manufacturing/ Assembly	over 3 million	yes/Latin & South America
THOMSON	Indianapolis, IN	1604	Components Manufacturing (Printed Boards & Cabinet Production)	Not applicable	no

THOMSON	Mocksville, NC	626	Cabinet Production	Not applicable	no
THOMSON	Marion, IN	1982	Tubes	Not available	yes/Europe
THOMSON	Circleville, OH	700	Glass for Picture Tubes	Not available	no
THOMSON	Scranton, PA	1242	Tubes	Not available	yes/Europe
TOSHIBA	Lebanon, TN	600 (300 add'l. planned for 1989)	Assembly	900,000 (1.3 million planned for 1989)	yes/Canada, South America, Japan & Taiwan
TOSHIBA	Horseheads, NY	1,000 (500 add'l. planned for 1989)	Tubes	1 million (1.5-2 million planned for 1989)	no/(probably will export in 1989)
TOSHIBA	Springfield, MO	2,000-2,500	Full Manufacturing/ Final Assembly	Not available	yes/Canada
ZENITH	Melrose Park, IL	2,500-3,000	Tubes	Not available	yes/Far East

Source: Electronic Industries Association, HDTV Information Center.

TABLE 11

U.S. Consumer Electronics Research Facilities, 1988

Name of Firm	Name of Facility	Location	Comments
Thomson	David Sarnoff Laboratories	Princeton, NJ	currently run by SRI with revenues from GE and RCA patents
Philips	Philips Laboratories	Briarcliff Manor, NY	
Zenith	n.a.	Glenview, IL	

Source: company annual reports.

A study done by Robert R. Nathan Associates (henceforth RRNA) for the EIA forecasts that 13 million HDTV receivers will be purchased in the United States in 2003 and that 92 percent of them will be made in the United States. The domestic content of these sets will be around 78 percent. The RRNA study projects that HDTV products will capture over 30 percent of the market for TVs by 2003. The production and sale of these receivers will contribute 23 billion dollars to the gross national product and will require the skills and efforts of 232,000 workers. The RRNA study argues that the production of HDTV receivers will increase the contribution of TV manufacturing to total GNP by six billion dollars more than would be the case if HDTV were not commercialized.[45]

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[45] Robert R. Nathan Associates, Inc., *Television Manufacturing in the United States: Economic Contributions—Past, Present and Future*, prepared for the Electronic Industries Association, Washington, D.C., November 22, 1988, Chapter IV, pp. 1, 4 and 20.

The RRNA study is echoed by a study done for the National Telecommunications and Information Administration. Using different assumptions and methodology, the author of that study concludes by saying that HDTV markets will support about 240,000 jobs in the United States and add around 7 billion dollars to total GNP by the year 2003.[46]

The assumptions and methods used by both these reports, and several others, are predictions, but the underlying fact is that all seem to confirm that HDTV products will be attractive to U.S. consumers, even though higher-priced than existing NTSC products, because consumers will want to see wider and larger pictures with higher resolution. The general confidence of all analysts in the demand side of the HDTV equation, therefore, makes it possible to focus attention seriously on the need to minimize, through measured public policies, the potential roadblocks to the commercialization of HDTV technology in the United States.

The RRNA study assumes, for example, that an HDTV standard will be adopted in 1991. It also assumes that the displays in HDTV receivers will be based on existing CRT technology. The assumptions are actually quite optimistic. Lengthy debates over the characteristics of the various proposals could very well delay the adoption of a standard for HDTV. A dramatic breakthrough in display technology outside the U.S. could rob the U.S. of a large proportion of the added-value that will come with the growth of HDTV markets. The results of the RRNA study, therefore, lend urgency to our recommendations in the next section for R&D consortia and for resolving the HDTV standards issues as soon as possible.

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[46] Larry F. Darby, Darby Associates, *Economic Potential of Advanced Television*, Washington, D.C., April 7, 1988, p. 43.

IX. SPECIAL POLICIES TO PROMOTE U.S. PARTICIPATION IN HDTV MARKETS

The main objective of U.S. policies toward HDTV should be to use the promotion of HDTV to strengthen overall U.S. competitiveness in world markets. We have argued already that the importance of HDTV derives from its centrality to the future of consumer electronics and from the place of consumer electronics in the electronics complex. HDTV, by itself, cannot make or break the electronics complex or turn the tide in U.S. electronics competitiveness, but it can make a contribution to what has to be a larger national effort.

To maximize the positive impact of HDTV promotional policies on the rest of manufacturing, and particularly on the electronics complex, policies must be chosen with an eye to maximizing the technological spinoffs from HDTV to other areas. Policies which favor HDTV at the expense of undermining the competitiveness of other key industries should be avoided.

A. HDTV Standards Policies

Adoption of uniform, national standards for HDTV program production and transmission will speed the development of a U.S.-based industry. Transmission standards should be developed through the FCC processes and through the development of industry consensus in other forums (see Appendix B). Japanese MUSE and European HD-MAC transmission standards for HDTV were developed for broadcasting and telecommunications environments that are different from that in the United States. These foreign standards were developed for DBS delivery. U.S. production and transmission standards will have to take into account our greater dependence on terrestrial transmission and cable systems. The FCC has already ruled that the existing stock of NTSC receivers, estimated to be around 140 million, must also receive signals sent out from HDTV terrestrial transmission.

The probable coexistence of at least three distinct and incompatible HDTV transmission standards for the United States, Japan, and Europe will not prevent Japanese and European firms from building HDTV equipment for the North American market. These firms already have established a significant manufacturing presence in the United States. The large size of the U.S. market and the lower value of the dollar relative to Japanese and European currencies since 1985 makes it possible for them to produce at globally competitive costs in the United States.

U.S.-owned firms have to be willing to reenter the market knowing that the consumer electronics market is an international market and will remain highly competitive. For this reason, any effort to delay the adoption of HDTV standards until some specific group of U.S.-owned systems firms can catch up to the international state of the art in HDTV technology will only result in the building of a "hot house" industry that is unlikely to be internationally competitve. If U.S. components producers are limited to supplying "hot house" U.S. systems firms, then they are unlikely to be competitive suppliers to foreign HDTV producers.

Similarly, the proposal to not adopt a standard for HDTV until the development of digital TV is unlikely to increase U.S. competitiveness in consumer electronics. It will be very difficult, if not impossible, to develop a digtal TV industry without the technological and manufacturing base that will be developed for HDTV. In addition, many of the other electronics industries will be hurt if a technological and manufacturing base for HDTV is not allowed to develop.

At the receiver end, one major proposal has been to develop an Open Architecture Receiver (OAR). Some proposals for an OAR are for a set that would be capable of processing an HDTV signal from various transmission media to the HDTV display and would allow owners of receivers to add on a variety of devices, such as cameras, keyboards, printers, and so forth, on the model of contemporary personal computers. Current manufacturers of TV receivers are skeptical of this proposal because of increased cost and creation of confusion among consumers.

In essence, the specific OAR proposal discussed above begs the question of transmission standards. It will be possible to reach compromises among the producers concerning the types of signal inputs that all receivers will be able to handle. Receiver manufacturers must be permitted to design television sets to deal with the possibility of signals from different transmission media. This type of receiver design will be easier if the standards for production and transmission allow for reasonable levels of "interoperability"—i.e., uniformity and simplicity in interfaces and conversion methods. The EIA supports a friendly multiport receiver, with separate inputs for RF and baseband signals, which is a form of open architecture. Such a system permits the necessary flexibility to accommodate all media without the costs and complexities of rigid open architecture burdening the receiver manufacturers.

The principal goals of the U.S. standard-setting process should be the development of an HDTV system which produces HDTV pictures (roughly twice the horizontal and vertical resolution of current NTSC pictures), permits a smooth transition from NTSC to HDTV broadcasting, and minimizes the use of scarce broadcast spectrum. These goals, taken together, constitute a major technological challenge. If this challenge can be met, then the United States will emerge with a very strong consumer electronics industry with major spinoffs for the electronics complex and the rest of American industry.

B. Meeting the Technological Challenge

The main technological roadblocks to the development and commercialization of HDTV equipment in the United States will be in four areas: 1) HDTV-related integrated circuits, 2) large displays, 3) new manufacturing technologies, and 4) broadband switching technologies. Much of the current interest in HDTV derives from the belief that there could be major technological spinoffs from HDTV for the rest of the electronics complex—and especially for semiconductors, computers, and telecommunications equipment. Proposed policies for the promotion of HDTV should be assessed in terms of their ability to generate such spinoffs.

In a current NTSC color TV set that costs around 270 dollars to manufacture, only about 20 to 30 dollars (7-11 percent) goes into the semiconductor components. In an HDTV set that costs around 2,000 dollars initially to manufacture, there will probably be no more than 400 dollars worth of semiconductor components, especially if there are no semiconductor-based alternatives to CRT displays by that time. These HDTV sets will not sell as rapidly as later models because of their high prices, but there will be major learning curves associated with HDTV set production and the average costs of production for HDTV semiconductors, displays, and cabinets will eventually come down toward current NTSC prices.

The RRNA study predicts that HDTV receivers will consitute 30 percent of the national market for TV receivers by 2003, or about 13 million sets. By that time, HDTV circuitry will cost only about 25 to 50 percent more than NTSC circuitry, or around 50-80 dollars per set. Thus, by 2003, the demand for semiconductors attributable to HDTV receivers will be no more than one billion dollars. This needs to be compared with Dataquest projections for total U.S. semiconductor sales of 44 billion dollars in that year.

Between the introduction of HDTV receivers (which RRNA says will occur around 1993) and 2003, it is possible that HDTV sets will provide a larger boost to total semiconductor demand. The key point, however, is that TV sets, even HDTV sets, will never be major items driving total semiconductor demand. It is much more likely that HDTV will become an important factor in the development of integrated circuit technology because of the new types of circuitry it requires.

There is an opportunity to use HDTV-related integrated circuits to promote the U.S. semiconductor industry because of the greater sophistication of circuitry in HDTV as compared with NTSC receivers. HDTV receivers will require more video memory, faster digital signal and video image processors, and more complex analog/digital hybrid circuits than NTSC receivers. Some of these circuit techniques will have uses outside consumer electronics. Video memories and video image processors will be important components in computers and computer workstations. Faster digital signal processors and analog/digital converters will be used in telecommunications equipment. To the extent that HDTV circuit technology has applications outside consumer electronics, there will be major spinoffs from its development.

The semiconductor industry in the United States is looking for a way of intensifying its efforts to reestablish its preeminent position in the world. It recently participated in the formation of an R&D consortium called Sematech, which addresses the need to improve semiconductor manufacturing process technology. The U.S. semiconductor industry, by and large, has gotten out of the business of supplying the consumer electronics markets. Only six percent of U.S. semiconductor output goes to consumer electronics, while in Japan the corresponding figure is over 40 percent. In order to regain lost ground in consumer-related semiconductors, U.S. firms need to get an early start in the development of HDTV-related chips. Thus, one fruitful approach might be to form an R&D consortium for the development of video-processing circuitry.

To the extent that public funds are made available for the promotion of HDTV, they should be focused on generic technological problems the resolution of which will benefit a large number of industries. For this reason, R&D consortia for HDTV-related integrated circuitry, large displays and electronic manufacturing technology seem particularly good candidates for public funding.

There does not necessarily have to be any public funding of R&D consortia. The main roles for the government in R&D consortia are to serve as a broker for the negotiations that produce them (usually this is done by the Department of Commerce) and to monitor them to prevent antitrust violations (this is done by the Department of Justice). In Sematech, the government provided part of the funding through the Department of Defense because it felt that semiconductor manufacturing technology had important implications for national security. The Defense Advanced Research Projects Agency (DARPA) has already indicated interest in cofunding an R&D consortium for HDTV displays for the same reason. But other R&D consortia, such as the Semiconductor Research Corporation (SRC), do not involve government funds.

Public funding of R&D consortia inevitably raises the issue of the participation of foreign-owned firms. In the case of HDTV technologies, it is quite likely that foreign-owned firms will want to participate and that domestic firms will want them to because of their strong technological base, their ability to contribute, and their high usage of components. It would be counterproductive to exclude foreign-owned firms from R&D consortia for

HDTV technologies, for reasons stated above. The key is not ownership but the level of commitment to R&D and manufacturing in the United States.

X. SUMMARY

One basic premise of this report is that competitiveness is primarily an economy-wide issue. There is a danger connected with equating the competitiveness of a nation with that of a single industry. While a single industry may be symbolic of general, national problems of competitiveness, certain policies designed to promote the revival of such symbolic industries may be prejudicial to the solution of the wider problem of competitiveness. For this reason, we recommend a judicious combination of economy-wide measures and industry-specific efforts. We recommend that economy-wide policies should focus on increasing investment levels in physical plant, human, and knowledge capital. In the case of measures specific to consumer electronics and HDTV, we recommend that only those which are likely to result in positive spin-offs for other industries should be the focus of public policies.

The development and commercialization of HDTV in the United States is an opportunity for the strengthening of U.S. competitiveness in the electronics complex and manufacturing more generally. HDTV is not the answer to all of America's problems in competitiveness, but it can contribute to their solution. Given the major presence of foreign-owned firms in the United States, there is an opportunity to build U.S. competitiveness with the help of those firms. Two main types of public policies are required to promote the HDTV industry in the United States: timely adoption of HDTV standards, and assistance in the formation of R&D consortia to develop indigenous HDTV technologies.

TABLE 1

Growth of real exports of goods and services in the OECD area *

Percentage changes from previous period

	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
United States	8.4	6.0	8.1	0.5	8.9	21.1	11.1	—3.5	5.7	2.6	11.0	14.1	9.1	0.9	—7.8	—3.8	6.8	—1.2	3.0	13.1
Japan	23.2	21.6	17.9	16.4	5.5	7.1	23.2	0.7	15.1	10.7	—0.7	6.2	17.7	15.6	3.6	4.2	17.5	5.6	5.2	3.7
Germany	12.7	9.7	6.5	6.5	6.5	10.1	12.1	—6.7	9.9	3.3	4.2	4.5	5.3	8.2	3.2	—0.5	9.0	6.8	0.0	0.8
France	11.2	16.1	16.3	9.2	12.0	10.8	8.8	—1.7	8.2	7.4	5.9	7.5	2.7	3.7	—1.7	3.7	7.0	1.7	0.7	1.7
United Kingdom	12.6	9.8	5.2	6.9	1.0	12.0	7.3	—2.8	9.1	6.8	1.8	3.7	0.1	—0.8	0.8	2.4	6.6	5.9	3.8	5.5
Italy	15.6	12.3	6.0	7.2	11.5	3.8	9.9	3.7	13.2	6.7	10.1	9.1	—4.3	7.5	—1.1	2.3	7.6	3.8	3.4	3.6
Canada	12.6	8.0	8.7	5.2	7.8	10.6	—2.0	—6.8	10.6	8.9	13.6	5.0	2.7	4.4	—2.2	6.4	17.7	6.0	4.1	5.9
Total of above countries	12.1	10.2	8.9	5.9	7.4	13.8	10.7	—3.1	9.1	5.5	6.4	3.4	6.2	4.9	—1.8	0.6	9.7	3.4	0.8	6.0
Austria	8.1	17.0	17.2	6.4	10.1	5.4	10.7	—2.4	11.1	4.6	6.0	10.8	5.8	3.8	1.9	3.3	6.6	6.9	3.2	1.6
Belgium	13.4	14.7	4.7	6.3	10.0	14.4	6.8	—8.9	11.7	12.7	3.4	7.1	3.3	3.1	2.2	3.2	5.7	1.2	5.7	6.3
Denmark	9.3	6.2	5.6	5.6	5.6	7.8	3.5	—1.8	4.1	4.1	1.2	8.4	5.2	8.2	2.5	4.9	3.5	4.3	0.7	4.9
Finland	10.0	16.7	8.7	—1.3	14.5	7.3	—0.6	—14.0	12.8	15.7	8.9	8.8	8.4	4.9	—1.1	2.5	5.4	1.2	1.3	1.7
Greece	—1.0	14.6	12.4	11.9	22.9	23.4	0.1	10.6	16.4	1.8	16.4	6.7	6.9	—5.9	—7.2	8.0	16.9	1.3	14.0	7.9
Iceland	—6.1	14.2	17.2	—3.9	10.7	8.5	—0.8	2.6	11.6	10.3	15.2	6.3	2.7	1.4	—9.7	10.3	3.0	11.0	6.2	4.0
Ireland	8.8	4.6	4.4	4.1	3.6	10.9	0.7	7.2	8.1	14.0	12.3	6.5	6.4	2.0	5.5	10.5	16.4	6.7	2.9	13.3
Luxembourg	10.7	13.8	9.0	5.3	5.3	14.2	10.6	—15.6	1.3	3.8	3.5	9.5	—1.2	—3.6	0.8	5.1	18.0	9.2	4.2	2.0
Netherlands	12.8	14.9	11.9	11.0	11.0	11.4	2.7	—3.1	9.9	—1.8	3.3	7.4	1.5	1.5	0.0	3.5	7.4	5.3	1.6	4.2
Norway	7.7	5.3	0.1	1.1	14.1	8.3	0.7	3.1	11.3	3.6	8.4	2.6	2.1	1.4	—0.1	7.6	8.2	6.9	1.9	2.0
Portugal	—3.4	2.9	—1.6	9.9	18.5	4.2	—15.7	—15.6	0.0	5.9	13.1	27.1	4.5	—3.0	6.0	16.7	14.2	11.0	7.0	10.2
Spain	18.4	15.5	17.4	13.0	12.2	9.0	0.8	—1.5	10.1	8.5	10.7	6.4	0.6	8.4	4.8	10.1	11.7	2.8	1.3	5.9
Sweden	7.6	11.5	8.6	4.8	5.9	13.7	5.3	—9.3	4.3	1.5	7.8	6.1	—0.5	1.1	4.4	10.7	6.7	2.2	3.3	2.5
Switzerland	10.0	13.3	6.8	3.9	6.4	7.9	1.0	—6.6	9.3	9.7	3.7	2.5	5.1	4.6	—3.0	1.0	6.4	8.3	0.4	1.7
Turkey	—	—	—	—	—	32.3	—20.9	—8.8	8.7	—18.4	3.5	4.4	—5.5	47.0	26.5	6.1	20.4	11.3	0.6	24.7
Total smaller European countries	10.5	12.6	8.6	6.8	10.0	11.1	2.4	—4.8	9.4	4.7	5.7	6.8	2.8	3.7	1.7	5.3	8.1	4.7	2.2	5.0
Australia	4.2	14.2	12.3	8.4	5.8	—2.0	—3.3	8.7	8.2	0.6	4.2	13.1	—1.5	—4.2	6.4	—2.7	16.1	9.9	4.8	9.5
New Zealand	17.2	3.6	10.2	4.9	—5.1	9.1	—2.3	3.8	14.8	0.8	0.7	6.3	3.1	3.4	—1.4	7.4	5.1	9.3	0.0	1.8
Total smaller countries	10.1	12.5	8.9	6.9	9.4	10.2	1.9	—3.8	9.4	4.4	5.5	7.2	2.5	3.2	2.0	4.9	8.5	5.1	2.4	5.3
Total OECD	11.6	10.8	8.9	6.2	7.9	12.8	8.3	—3.3	9.2	5.2	6.3	8.1	5.3	4.5	—0.9	1.7	9.4	3.8	1.2	5.8
Four major European countries	12.8	11.3	7.9	7.3	6.8	9.8	9.8	—3.2	9.8	5.6	4.8	5.7	1.8	4.8	0.9	1.5	7.7	5.0	1.3	2.6
OECD Europe	11.8	11.8	8.2	7.1	8.1	10.4	6.7	—3.8	9.6	5.2	5.2	6.1	2.2	4.4	1.2	3.0	7.9	4.9	1.7	3.6
EEC	12.5	11.8	8.2	7.8	7.9	10.4	7.8	—3.5	9.7	5.4	4.9	6.2	2.0	4.3	1.1	2.6	7.9	4.7	1.8	3.5
Total OECD *less* the United States	12.6	12.3	9.2	7.8	8.6	9.7	7.4	—3.2	10.3	6.0	4.9	6.2	4.0	5.7	1.4	3.3	10.1	5.2	0.8	3.9

*** Aggregates were computed on the basis of 1982 exchange rates.**

Source: OECD Economic Outlook, December 1988.

TABLE 2

Growth of real imports of goods and services in the OECD area [a]

Percentage changes from previous period

	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
United States	15.5	7.8	4.3	5.1	11.7	11.9	-2.0	-10.3	18.5	11.1	7.0	4.1	-6.0	3.4	-2.2	9.6	23.9	3.4	9.4	7.9
Japan	12.5	14.1	22.3	5.6	9.9	24.2	6.2	-9.8	5.2	8.2	5.1	13.4	-6.2	5.1	1.7	-5.1	11.1	-0.1	2.8	9.2
Germany	12.1	16.4	15.7	10.0	5.7	4.3	2.2	-0.6	10.5	3.6	5.5	10.5	3.7	-1.2	-0.1	0.6	5.3	3.7	3.6	4.9
France	13.3	22.4	7.4	6.3	13.2	14.2	1.9	-9.7	17.4	0.1	3.0	10.1	2.5	-2.1	2.6	-2.7	2.7	4.3	7.3	6.4
United Kingdom	8.0	2.9	5.0	5.2	10.1	12.3	0.9	-7.0	4.7	1.5	3.8	9.7	-3.2	-2.7	4.9	6.2	9.7	2.6	6.5	7.3
Italy	5.6	19.4	15.9	2.4	11.4	10.5	2.2	-9.6	15.4	-0.2	8.1	13.8	8.3	-3.8	-0.7	-1.6	11.0	4.7	4.7	10.0
Canada	9.8	13.1	-1.7	7.2	13.8	14.7	11.1	-3.3	8.6	1.7	7.4	11.4	4.9	8.5	-16.2	9.0	17.1	8.4	7.3	8.6
Total of above countries	12.2	12.0	9.5	6.1	10.4	12.7	1.8	-7.7	12.4	4.8	5.8	9.0	-1.2	1.2	-0.8	3.0	13.5	3.4	6.6	7.6
Austria	7.1	9.5	15.9	6.3	12.1	9.6	6.9	-4.6	17.4	8.0	-1.3	11.8	6.4	-1.5	-3.3	5.7	9.9	6.9	0.2	4.4
Belgium	13.9	14.6	12.5	5.3	8.4	19.4	7.5	-9.8	11.0	15.4	3.7	9.1	0.3	-2.3	1.1	-0.8	6.0	0.8	7.6	8.4
Denmark	4.9	13.1	9.3	-0.7	1.5	12.8	-3.8	-4.8	15.6	0.0	0.1	5.0	-6.8	-1.7	3.8	1.8	5.5	8.7	6.4	-1.3
Finland	3.9	22.3	20.3	-0.6	4.2	13.0	6.7	0.6	-2.0	-1.5	-3.7	18.4	8.3	-4.7	2.5	3.0	1.0	6.8	3.1	9.0
Greece	10.3	15.5	6.2	7.6	15.4	32.2	-16.3	6.3	6.1	8.0	7.2	7.2	-8.0	3.6	7.0	6.6	0.2	12.8	3.8	8.1
Iceland	-9.0	-12.1	27.8	23.0	0.2	18.6	12.8	-12.3	-3.5	20.2	3.6	2.5	3.0	7.2	-1.1	-5.7	9.3	9.7	0.3	22.9
Ireland	15.6	13.4	2.3	4.7	5.1	19.0	-2.3	-10.2	14.7	13.3	15.7	13.9	-4.5	1.7	-3.1	4.7	9.9	3.3	5.5	4.9
Luxembourg	9.1	11.2	19.0	6.5	2.8	10.6	5.8	-8.7	0.8	1.6	5.9	7.1	3.1	-2.8	-0.1	1.9	15.4	6.2	0.5	3.5
Netherlands	13.0	14.1	14.7	5.7	9.1	8.9	-6.8	-3.9	10.4	2.4	6.2	6.5	-1.0	-5.9	1.1	3.8	5.1	6.6	3.9	5.6
Norway	2.2	1.8	13.6	6.4	-1.0	14.4	4.7	7.0	12.3	3.4	-13.5	-0.7	3.3	1.5	3.7	0.0	9.5	5.9	10.4	-6.8
Portugal	33.0	7.6	0.9	14.5	12.0	12.7	4.8	-25.2	3.4	12.0	-1.6	8.7	10.5	3.7	5.4	-8.7	-2.7	3.9	17.2	24.1
Spain	8.1	15.8	7.0	0.7	24.7	16.4	7.7	-1.1	10.1	-4.7	-0.7	11.5	3.8	-4.2	3.9	-0.6	-1.0	6.2	16.5	20.4
Sweden	8.3	12.9	10.4	-3.3	4.0	6.9	9.9	-3.5	9.0	-3.8	-5.5	11.6	0.4	-7.1	4.3	0.4	4.5	8.0	5.5	6.3
Switzerland	8.3	12.9	13.9	6.2	7.3	6.5	-1.0	-15.4	13.1	9.3	10.9	6.9	7.2	-1.3	-2.6	4.4	7.1	5.1	7.1	5.4
Turkey	—	—	—	—	—	10.4	1.7	11.8	24.1	-8.9	-31.4	-7.9	-4.6	16.5	13.4	12.7	15.5	7.7	13.1	18.8
Total smaller European countries	9.5	12.9	12.1	3.8	8.3	12.4	1.6	-4.8	11.0	3.9	0.3	-8.0	1.2	-2.5	1.8	2.1	5.4	5.8	7.0	7.5
Australia	12.6	2.5	5.6	-0.8	-8.2	22.3	25.5	-15.9	12.0	0.3	4.1	2.3	4.9	9.4	5.1	-10.8	20.7	5.6	-2.9	3.2
New Zealand	-5.5	7.5	17.1	1.9	6.3	18.3	22.9	-22.0	-2.0	2.4	-5.2	16.5	-3.9	4.6	6.8	-6.0	17.5	-3.1	2.2	11.2
Total smaller countries	9.4	11.9	11.7	3.5	7.2	13.1	3.4	-6.0	10.8	3.7	0.5	7.8	1.4	-1.6	2.1	1.0	6.7	5.6	6.1	7.3
Total OECD	11.4	12.0	10.1	5.3	9.6	12.8	2.3	-7.2	11.9	4.5	4.3	8.7	-0.6	0.5	0.0	2.4	11.7	4.0	6.5	7.5
Four major European countries	10.1	14.3	11.0	6.7	9.4	9.6	1.8	-5.9	11.5	1.6	4.9	0.8	2.6	-2.2	1.5	0.6	6.7	3.8	5.3	6.7
OECD Europe	9.8	13.7	11.4	5.5	9.0	10.8	1.7	-5.4	11.3	2.6	3.0	9.6	2.1	-2.3	1.6	1.2	6.2	4.6	6.0	7.1
EEC	10.7	14.2	11.0	6.0	9.7	11.0	1.1	-5.9	11.2	2.7	4.6	0.0	1.7	-2.5	1.7	0.8	5.9	4.2	6.0	7.4
Total OECD *less* the United States	10.1	13.3	11.9	5.4	10.2	13.0	3.5	-6.4	10.2	2.6	3.5	10.1	1.1	-0.4	0.6	0.4	7.9	4.2	5.4	7.4

[a] Aggregates were computed on the basis of 1982 exchange rates.

Source: OECD Economic Outlook, December 1988.

TABLE 3

Competitive positions

Indices, 1982 = 100

	1986	1987	1988	1989	1990	1986	1987	1988	1989	1990
	Manufacturing unit labor costs in local currency					Export prices of manufacturers in local currency				
United States	95	94	94	95	98	93	91	91	93	96
Japan	96	93	89	89	89	79	74	72	72	72
Germany	105	108	108	110	112	103	101	100	102	104
France	123	123	119	120	121	126	128	132	135	137
United Kingdom	108	109	111	114	119	129	134	137	140	143
Italy	128	131	134	137	140	127	128	133	136	141
Canada	100	102	102	105	109	111	112	110	112	115
Austria	104	106	106	107	108	104	101	102	103	105
Belgium-Luxembourg	104	105	107	109	110	118	113	115	118	120
Denmark	122	131	133	138	142	127	127	132	136	141
Finland	115	117	123	126	131	117	120	124	129	134
Netherlands	97	99	98	98	99	99	93	94	95	97
Norway	126	137	145	149	154	123	131	138	142	146
Spain	127	134	140	145	151	150	154	161	168	174
Sweden	123	128	136	144	151	130	133	139	145	151
Switzerland	115	118	121	124	127	113	113	115	119	122
Australia	123	128	135	143	149	137	156	170	172	178
New Zealand	125	134	140	144	147	140	147	152	157	163

TABLE 3—Continued

	1986	1987	1988	1989	1990	1986	1987	1988	1989	1990
	Relative unit labor costs in manufacturing, in a common currency					Relative export prices of manufacturers, in a common currency				
United States	87	74	69	68	69	86	76	70	70	71
Japan	144	148	151	152	148	118	118	123	124	121
Germany	108	114	113	112	112	104	107	103	103	102
France	106	103	97	95	94	107	108	108	107	106
United Kingdom	82	79	84	86	87	95	96	103	104	104
Italy	105	105	103	103	103	103	102	101	101	102
Canada	88	91	96	97	98	101	103	107	107	107
Austria	101	103	102	101	100	102	102	103	101	101
Belgium-Luxembourg	97	99	99	99	98	108	107	108	107	107
Denmark	114	123	120	120	121	118	120	121	120	121
Finland	98	97	102	102	103	99	101	104	106	107
Netherlands	97	101	99	96	95	96	98	96	95	95
Norway	99	101	104	103	104	95	97	100	99	99
Spain	90	92	98	101	103	105	106	113	116	118
Sweden	98	97	101	105	108	102	102	105	108	109
Switzerland	116	121	122	122	123	113	118	119	118	118
Australia	74	72	80	88	90	85	92	106	111	112
New Zealand	82	90	97	93	93	95	101	108	104	105

Source: OECD Economic Outlook, December 1988.

TABLE 4

Productivity trends in selected OECD countries

Business sector, compound annual growth rates [a]

	OECD average [b]	United States	Japan	Germany	France	United Kingdom	Italy	Canada	Austria	Belg
Total factor productivity										
Pre-1973 [c]	2.8	1.5	6.3	2.6	3.9	1.9	4.8	2.3	2.8	3.7
1974-1979	0.7	—0.1	1.8	1.8	1.8	0.2	1.6	1.1	1.8	1.4
1980-1986	0.6	0.1	1.7	0.8	1.2	1.0	0.7	—0.3	0.7	1.3
1987-1990	1.2	0.8	2.2	1.3	1.8	1.8	1.6	—0.2	1.2	0.8
Labor productivity										
Pre-1973 [c]	4.2	2.2	8.8	4.7	5.6	3.3	6.6	3.0	5.3	4.8
1974-1979	1.6	0.3	3.2	3.4	3.2	1.3	2.4	2.0	3.9	2.8
1980-1986	1.4	0.7	2.8	2.0	2.4	1.9	1.3	1.1	2.0	2.4
1987-1990	1.9	1.3	3.5	2.3	2.7	2.2	2.4	0.8	2.3	1.8
Capital productivity										
Pre-1973 [c]	—0.4	0.3	—2.0	—1.2	0.3	—0.9	0.6	1.3	—2.5	1.0
1974-1979	—1.4	—0.8	—2.9	—1.0	—1.4	—2.0	—0.3	—0.3	—2.5	—1.8
1980-1986	—1.4	—1.0	—2.0	—1.3	—1.3	—0.8	—0.6	—2.6	—2.0	—1.2
1987-1990	—0.6	—0.1	—2.2	—0.5	—0.1	0.9	—0.4	—1.8	—0.9	—1.4

TABLE 4—Continued

	Den-mark	Finland	Greece	Ireland	Nether-lands	Norway	Spain	Sweden	Switzer-land	Aus-tralia
Total factor productivity										
Pre-1973 [c]	1.7	3.3	6.6	4.6	2.7	2.7	2.6	1.7	1.6	1.8
1974-1979	0.1	1.6	1.9	3.3	2.1	2.2	0.9	0.9	—0.8	0.6
1980-1986	0.8	1.6	—0.5	2.6	0.8	1.2	0.8	0.2	0.7	0.4
1987-1990	—0.8	2.4	0.5	2.3	1.1	0.4	0.8	0.5	0.3	—0.2
Labor productivity										
Pre-1973 [c]	3.5	4.8	8.5	5.2	4.4	4.2	5.8	3.4	3.4	2.9
1974-1979	1.6	3.1	3.1	3.8	3.5	3.9	3.9	2.2	0.7	1.9
1980-1986	1.6	2.3	0.2	3.7	1.7	2.0	2.6	1.2	1.5	1.0
1987-1990	0.2	3.5	1.1	2.8	1.8	1.4	1.5	1.6	1.3	0.3
Capital productivity										
Pre-1973 [c]	—1.8	—0.1	—0.9	2.4	0	0.6	—4.5	—1.4	—1.9	—0.3
1974-1979	—3.0	—1.7	—3.0	1.0	0	—0.2	—5.7	—1.7	—4.0	—1.8
1980-1986	—0.6	0.1	—2.9	—1.6	—0.7	0.2	—3.1	—1.9	—1.0	—0.8
1987-1990	—2.8	—0.3	—2.0	0.4	—0.1	—0.9	—0.8	—1.6	—1.7	—1.1

[a] Data for 1987 to 1990 are OECD estimates and projections.

[b] Weighed average of countries based on the 1985 business sector output at 1985 prices and exchange rates.

[c] United States 1960-73, Japan 1966-1973, Germany 1960-1973, France 1964-1973, United Kingdom 1960-1973, Italy 1960-1973. Canada 1961-1973, Austria 1960-1973, Belgium 1960-1973, Denmark 1960-1973, Finland 1961-1973, Greece 1961-1973, Ireland 1960-1973, Netherlands 1961-1973, Norway 1963-1973, Spain 1964-1973, Sweden 1963-1973, Switzerland 1962-1973, Australia 1960-1973.

Note: Total factor productivity = real gross value added (at factor cost)/total factor inputs (1985 weights).
Labor productivity = real gross value added/private sector employment, including self-employed.
Capital productivity = real gross value added/gross capital stock (constant prices).

Source: OECD, Economic Outlook, December 1988.

TABLE 5
International Costs

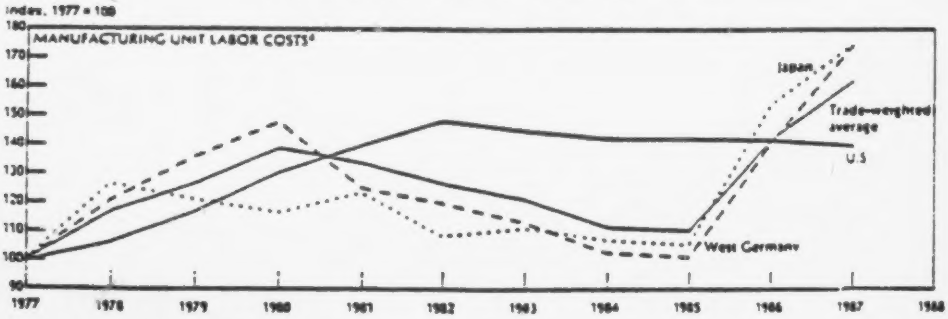
Manufacturing Output Per Hour, Hourly Compensation, and Unit Labor Costs

Average annual rates of change

	Productivity			Labor compensation[a]		
	1973-87	1986	1987	1973-87	1986	1987
United States	2.5	3.7	2.8	7.3	3.3	1.3
Canada	2.1	—0.2	1.7	7.2	2.1	9.5
Japan	5.3	1.7	4.1	12.9	48.6	18.1
France	3.9	2.2	3.7	10.5	35.7	19.1
West Germany	3.3	1.7	1.3	10.2	41.6	25.6
United Kingdom	3.2	2.8	6.9	10.8	21.8	20.9
Weighted average, 11 foreign countries	3.8	1.4	3.4	10.4	30.3	18.3

	Unit labor costs[b]			Unit labor costs[a]		
	1973-87	1986	1987	1973-87	1986	1987
United States	4.7	—0.4	—1.5	4.7	—0.4	—1.5
Canada	7.1	4.1	2.7	5.0	2.4	7.7
Japan	2.6	3.2	—2.5	7.3	46.1	13.5
France	8.7	2.5	—0.2	6.4	32.9	14.9
West Germany	3.8	2.7	2.7	6.7	39.2	23.9
United Kingdom	10.5	4.8	1.1	7.4	18.5	13.0
Weighted average, 11 foreign countries	5.0	3.4	0.8	6.4	28.5	14.4

International Manufacturing Costs



[a] U.S. dollar basis.

[b] National currency basis.

NOTE: The 11 foreign countries are Belgium, Canada, Denmark, France, Italy, Japan, the Netherlands, Norway, Sweden, the United Kingdom, and West Germany.

SOURCE: U.S. Department of Labor, Bureau of Labor Statistics.

TABLE 6

(a) Total Defense and Nondefense R&D Shares of GDP

(Percent)

	Total			Defense			Nondefense		
	1981	1983	1985	1981	1983	1985	1981	1983	1985
U.S.	2.45	2.62	2.83	.61	.75	.85	1.84	1.87	1.96
Japan	2.32	2.56	2.81	.01	.01	.02	2.31	2.55	2.79
Germany	2.45	2.54	2.66	.10	.11	.14	2.35	2.43	2.52
France	2.01	2.15	2.31	.50	.46	.46	1.51	1.69	1.85
U.K.	2.42	2.27	2.33	.69	.66	.68	1.73	1.61	1.65
Canada	1.32	1.35	1.38	.03	.04	.04	1.29	1.31	1.34

(b) Business-Funded R&D as Shares of GDP

	1972	1981	1983	1985	(est.) 1986
U.S.	0.99	1.22	1.32	1.39	1.42
Japan	1.15	1.73	1.99	2.09	2.14
Germany	1.08	1.46	1.56	1.64	1.69

Sources: OECD Science and Technology Indicators data base; and Office of Technology Assessment, *International Competition in Services: Banking, Building, Software, and Know-how* (Washington, July 1987).

TABLE 7

Profits and investment in the business sector

	1971-80	1981-85	1986-90	1987	1988	1989	1990
Capital/output ratio (1982=100)							
Major seven countries	90.3	98.4	98.9	98.6	98	99	100¼
United States	89.6	96.5	93.9	93.9	93	93½	94½
Japan	88.7	101.0	109.8	107.9	108¾	111¼	114½
Germany	90.5	99.2	100.6	100.6	101	101	101¼
				Per cent			
Investment share [a], constant prices [b]							
Major seven countries	16.4	16.2	17.3	16.5	17½	18	18½
United States	13.9	14.6	14.6	14.0	14¾	15	15¼
Japan	22.9	22.2	26.0	24.3	26½	27¾	28
Germany	15.4	15.0	16.3	15.7	16¼	17	17¼
Investment share, current prices [a]							
Major seven countries	16.2	15.6	15.2	14.6	15¼	15½	15¾
United States	13.4	13.8	12.3	12.1	12¼	12½	12½
Japan	23.1	20.9	22.1	20.9	22¼	23¼	23¼
Germany	15.2	14.9	15.4	14.9	15¼	16	16¼
Profit share[c]							
Major seven countries	42.8	42.6	43.5	43.6	43½	43½	43½
United States	39.8	40.2	39.9	40.3	39¾	39¾	39½
Japan	48.0	44.5	44.5	44.6	44½	44½	44½
Germany	41.8	42.9	46.1	45.4	46¼	46¾	47

TABLE 7—Continued

	1971-80	1981-85	1986-90	1987	1988	1989	1990
	Percent						
Net profit rate [d]							
Major seven countries	10.1	4.9	6.7	6.7	6¾	6½	6¾
United States	12.5	6.6	8.9	8.8	8¾	8¾	9¼
Japan	6.2	0.2	2.9	3.1	3¼	2¼	2¾
Germany	6.6	4.6	7.3	7.2	7½	7½	7½

[a] Ratio between fixed investment and output.

[b] The base year for the constant prices series differs across countries; therefore the levels of the ratios are not comparable between countries.

[c] Ratio between non-wage value added and output, at current prices.

[d] Difference between net rate and real long-term interest rate. The net rate of return is defined as the ratio between non-wage value added and capital stock.

Source: OECD Economic Outlook, December 1988.

TABLE 8

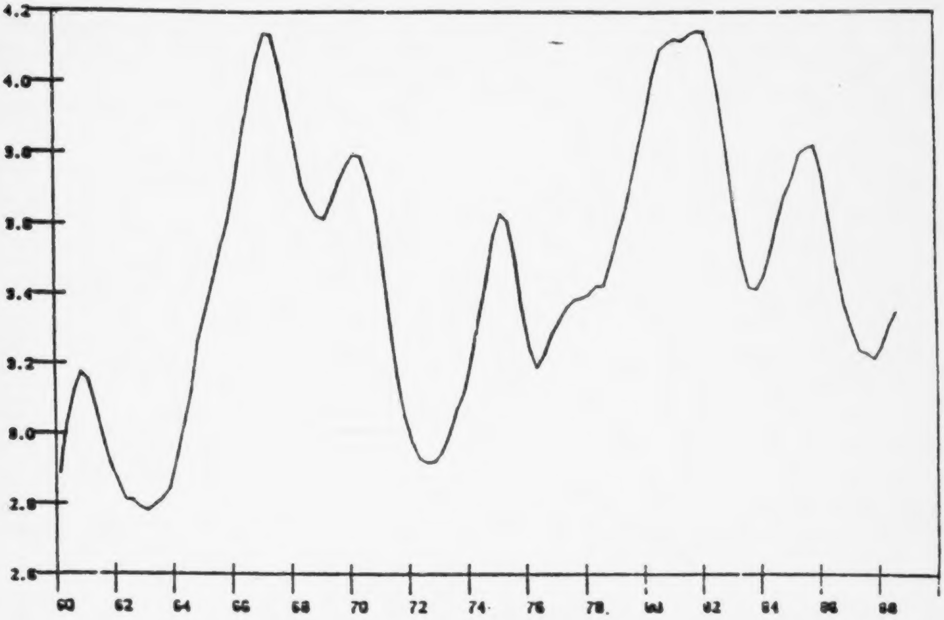
Electronics Trade Balance (Billions of dollars)[a]

Year	Semicon	Telequip	RadioTV	Computer
1972	.140	—.010	.353	1.341
1973	.230	—.013	.152	1.717
1974	.287	—.002	.190	2.198
1975	.251	.105	.259	2.229
1976	.293	.133	—.256	2.588
1977	.151	.128	.193	3.264
1978	.156	.155	.745	3.424
1979	.180	.129	.840	4.516
1980	.143	.136	.832	6.427
1981	.010	.158	.564	6.967
1982	—.374	.203	.229	6.764
1983	—.621	—.419	.020	6.070
1984	—2.337	—1.040	—.113	5.677
1985	—1.491	—1.196	—.810	5.679
1986	—1.138	—1.335	—.795	3.542
1987	—1.006	—1.450	—.750	3.466

[a] These estimates of the electronics trade balance are based on Department of Commerce numbers reported in the 1988 edition of *Industrial Outlook*. Because of the exclusion of many kinds of electronics products, such as electronic componentry other than semiconductors, and consumer electronics products other than radios, televisions and related products such as VCRs, these estimates are based on a narrow definition of the electronics sector. A broader definition, such as the one used in Figure 4, suggests a much larger trade imbalance in electronics. Both definitions show the U.S. trade position deteriorating over time even on computers, an area in which the U.S. has a technological and competitive advantage.

FIGURE 1

New P&E Expenditures by Business—Manufacturing as a % of GNP



88:2 & 88:3 based on planned expenditures published by the BEA.

Assumed 7% GNP growth in 3rd qtr. of '88

4 quarter moving average

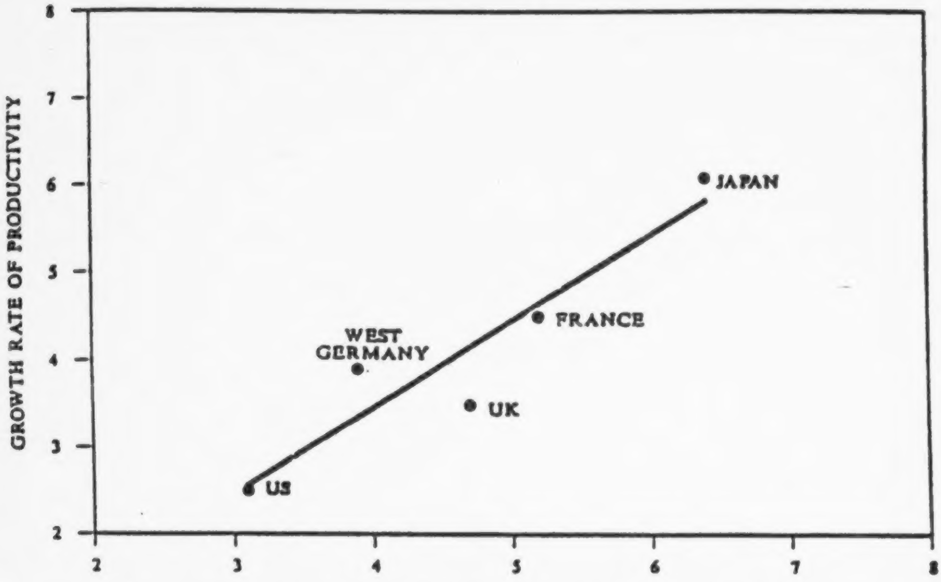
The sharp appreciation of the dollar not only depressed exports; it also squeezed the manufacturing investment share of GNP.

Source: David Hab, Kemperer Financial Services.

FIGURE 2

PRODUCTIVITY VS. THE CAPITAL-LABOR RATIO IN MANUFACTURING

(AVERAGE ANNUAL GROWTH RATES, 1970-1986)

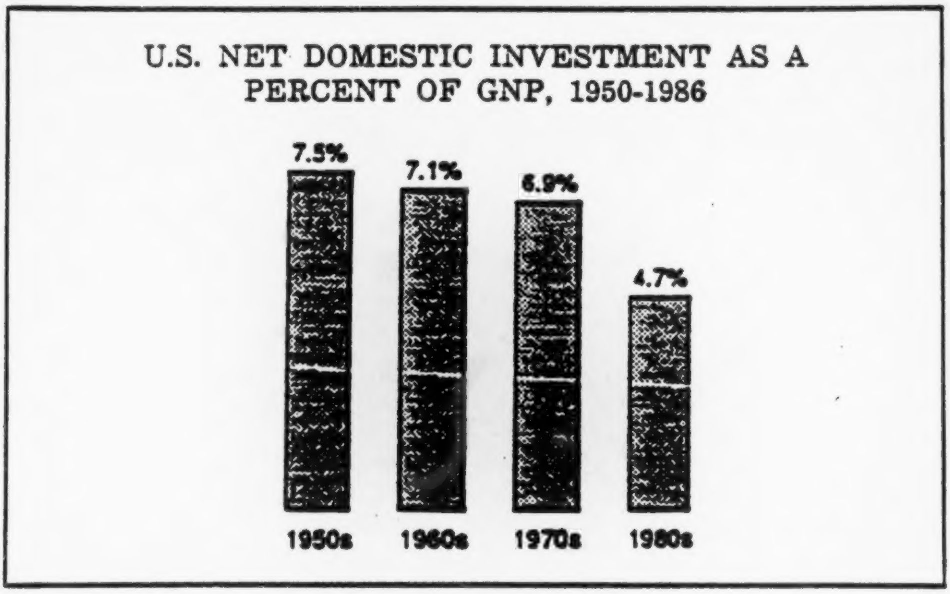


GROWTH RATE OF THE CAPITAL-LABOR RATIO

Sources: U.S. Department of Labor, Bureau of Labor Statistics
U.S. Department of Commerce, Bureau of Economic Analysis
Organization for Economic Cooperation and Development

Source: George Hatsopoulous, Paul Krugman and Larry Summers, "Beyond the Trade Deficit," *op. cit.*

FIGURE 3

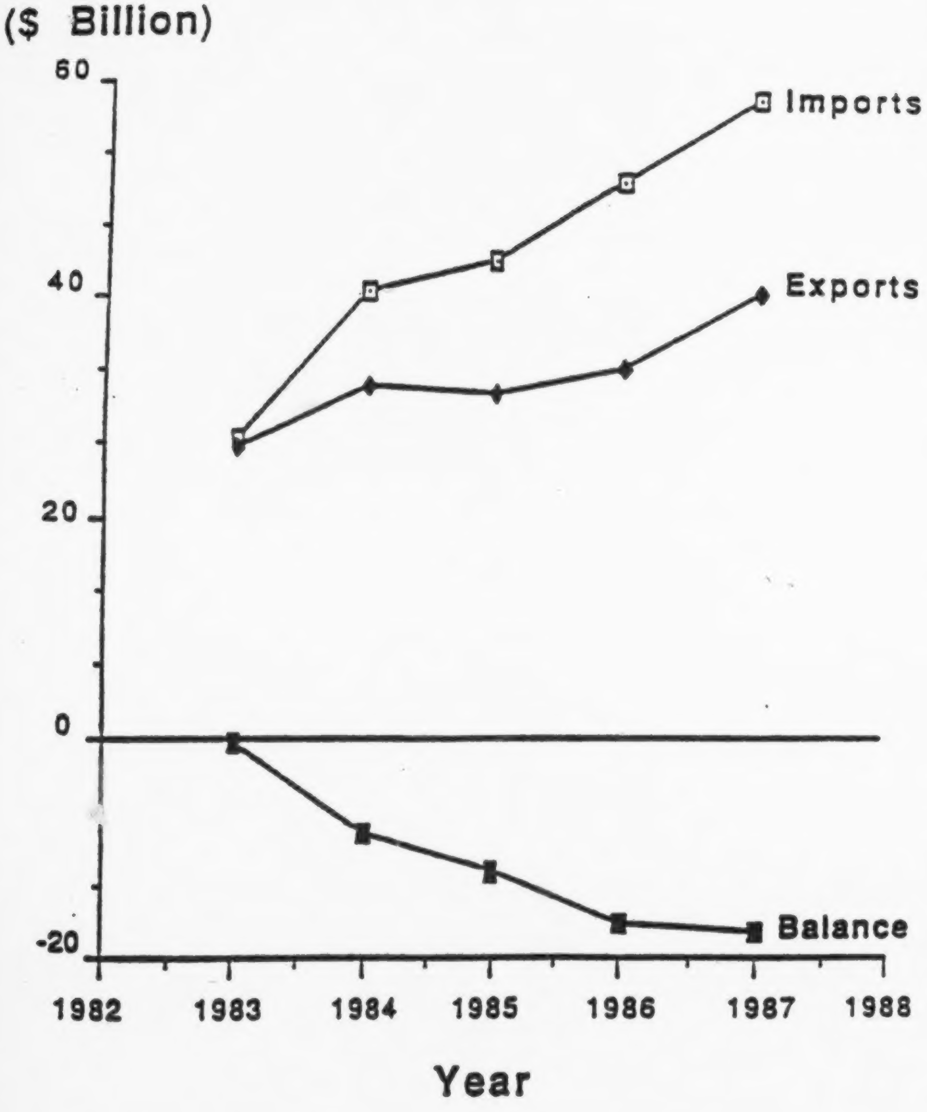


Source: *Economic Report of the President,* 1987

Source: *The Cuomo Commission Report* (Simon and Schuster, 1988).

FIGURE 4

U.S. BALANCE OF TRADE
Total Electronics Industries
1983—1987

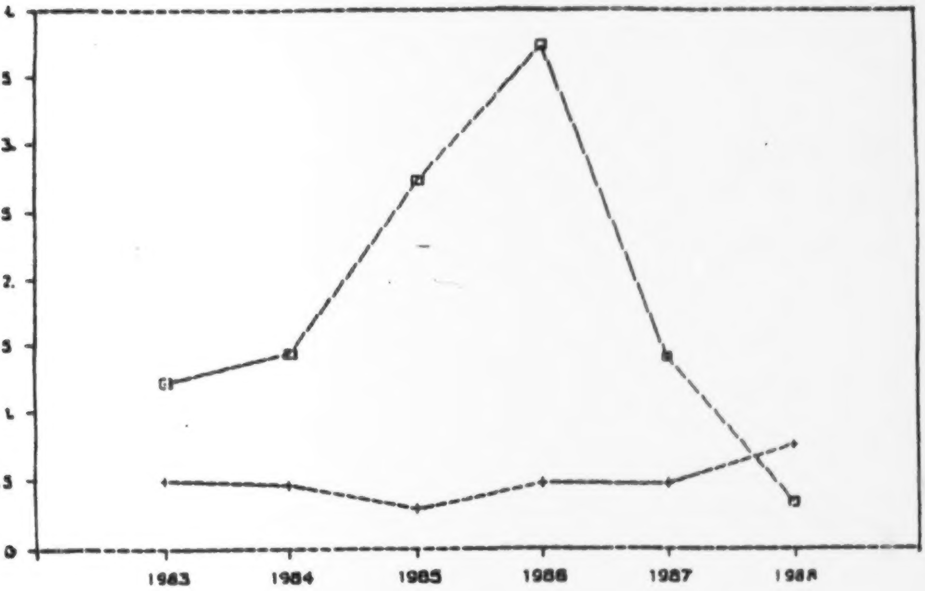


Source: Susan Walsh Sanderson graph based on Department of Commerce data.

FIGURE 5

U.S. INDUSTRY COLOR TUBES/KITS

Imports & Exports



YEAR

□ IMPORTS + EXPORTS

(Units in Millions)

Source: Joseph Donohue, Thomson Consumer Electronics

Testimony of
Dr. James J. Tietjen
David Sarnoff Research Center
Before the
Senate Committee on Governmental Affairs
Senator John Glenn, Chairman
August 1, 1989

Mr. Chairman and Members of the Committee, I appreciate the opportunity to appear before you this morning to discuss High Definition Television (HDTV) technology and its possible impact in the United States.

This Committee is to be commended for its interest and initiative on this issue. It is important that we develop a national strategy for HDTV development in this country. This is a very complex subject with many ramifications, and it is important that we all try to understand it as well as we possibly can.

I am President and Chief Operating Officer of the David Sarnoff Research Center in Princeton, New Jersey, a subsidiary of SRI International of Menlo Park, California, an American Company. We were formerly RCA Laboratories, inventors of the NTSC color television system currently in use in the United States, Japan, and other countries comprising about one-half of the world's television viewers. In addition to the NTSC system, the Sarnoff Center has also developed many of the critical components and technologies responsible for today's television and semiconductor industries, including camera technology, color television picture tubes, addressable liquid crystal displays, and the CMOS technology used by the semiconductor industry around the world -- to name but a few. In addition to Sarnoff's direct involvement in technology development, I have had substantial experience transferring technology into the marketplace, and I am quite familiar with the business environment of the various industries related to HDTV.

At present Sarnoff is working to develop an advanced television transmission system specifically designed to meet the unique needs of the American viewing public and television industry. Our system is called Advanced Compatible Television (ACTV). It is a two-step, evolutionary approach for moving America into the advanced television era quickly, and in a manner which will not leave us disadvantaged relative to foreign economies.

You asked me to comment on: "What will be the impact of HDTV technology on a variety of related industries?" To answer this question, I would like to focus upon four areas. First, we can draw upon the history of color television and the dual-use technologies which have been derived from it. Second, there is a growing convergence of technologies derived from different industries, indicating that each will rigorously impact and enhance the others. Third, for the United States to have any impact, we must set an HDTV standard as rapidly as is practical. And last, to insure our industrial competitiveness in this and related areas, government support and action are imperative.

Let us consider the validity of the "dual-use" technology concept of high definition television which has received so much attention lately. For example, how important is HDTV technology to the computer industry, and vice-versa? Looking back into the past, there are paradigms which illustrate a close sharing of technologies. It's clear that conventional television was built around the invention of the cathode-ray tube display and vacuum-tube based image pick-up tubes, or cameras. Now, it is interesting to note that the computer industry, particularly the personal computer industry, inherited the cathode ray tube technology from television. In the late 1970's, during the birth of the personal computer industry, the display technology that was required existed; it was low-cost, it was already high-volume. By incorporating this technology, borrowed from television, the computer industry was, in a sense, liberated from a costly and time-consuming development, thereby enabling the industry to concentrate on developing the market for personal computers.

Today, consumer electronics contribute to industrial and defense electronics. For example, much of the frontier research in photo-electronics is being carried out by consumer electronics companies manufacturing laser disks. Photo-electronics are of growing importance in communications and computers and may soon become critical path technologies for the most advanced space communications systems and supercomputers. The market size and production base of consumer electronics provides the financial capacity and the manufacturing know-how to develop photo-electronics. U.S. defense industries and space industries are greatly assisted in the funding of the prerequisite research needed to support the development and manufacturing capabilities ultimately required for their pursuits.

Beyond these examples, there is the simple fact that we are witnessing a rapid convergence of technologies. As development and innovation draw technologies closer together, the impact of one upon another will be more vigorous. Advanced television is a beneficiary of the digital integrated circuit and semiconductor memory technology developed for the computer industry. HDTV technology would not exist without the technological developments that have been primarily funded by the computer industry. Conversely, computers will use more and more video displayed on higher resolution screens, and HDTV receivers will have a high semiconductor and memory content. And, the telecommunications industry will benefit from both of these things. There is still a long way to go in these technology developments and industry interaction is likely to expand. For example, a true consumer HDTV display is not available yet by anyone, that I know of, around the world, and it may be some time before this component is developed. As it emerges, it likely will impact more than just the consumer electronics industry.

High definition television will "de-mature" the television industry, giving rise to new services, new programs, new transmission systems, and new receiver sets. HDTV will, over time, replace the current television industry with an entirely new one. These new elements will stimulate economic growth as the industry responds to new opportunities, in substituting for old businesses and in identifying entirely new ones. There are many estimates of the size of the new television industry and the impact on the TV industry suppliers. All indicate that this is a significant industrial growth opportunity.

And while the attention surrounding HDTV has focused on its inherent consumer orientation; as DARPA has recognized, it has a variety of other potential applications. The high definition television cluster of technologies constitutes a strategic set which will affect many industries, including defense. In a rather brief cursory attempt to identify those which would be affected, we came up with many different industries. These include electronics, communications, computers, medical, publishing, avionics, postal services, etc. The continued development of this technology base is of utmost importance to the vitality of the U.S. research development, and production within the U.S. is essential to ensure the soundness of our technology base and its accessibility at reasonable price to other industries.

While it seems rather clear that HDTV will, in fact, have a substantial impact on a variety of industries, the degree of impact and the timing is very uncertain. The specific HDTV transmission standard is likely to play a significant role in establishing the dynamics of the U.S. transition into the HDTV era. Without knowledge of the specific standard to be chosen, it is extremely difficult to predict HDTV timing and growth rates.

For the reasons I have discussed, I feel it is very important for the government to help ensure that the United States establishes a strong position in HDTV technology and expertise. We cannot afford to ignore the potential impact and ripple effects of this technology.

One very important issue is the establishment of an HDTV standard which will result in the most robust and the fastest growing HDTV industry. What is needed is a single standard for all television delivery media which can be implemented rapidly so that the U.S. HDTV industry can develop quickly and not fall behind the power curve versus Japan and Europe. The FCC's Advisory Committee on Advanced Television Service, under the leadership of Richard Wiley, is making excellent progress toward selecting a transmission standard. We do need to move quickly. If we wait too long, we may find ourselves behind and unable to catch up in a critical technology race with broad implications for a variety of strategic industries.

Thank you.

The demand for high-resolution systems

Testimony of
Richard Jay Solomon
before the Committee on Governmental Affairs
United States Senate

Hearings on
The Scope of the HDTV Market and Its
Implications for Competitiveness
August 1, 1989

I appreciate this opportunity to comment on the important issues being discussed here today. My name is Richard Jay Solomon. I am a consultant in telecommunications policy, and speak as a private citizen. Since 1978, I have been a research associate in communications technology and policy at the Massachusetts Institute of Technology where I am a currently working on several projects related to high-resolution systems. I am also an Adjunct Professor at the Interactive Telecommunications Program at New York University.

Over the last ten years industry-government consortia in Japan and Europe have invested over a billion dollars in R&D in the area of high-resolution systems. Thus far, the lone American, purely private consortium — the Center for Advanced Television Systems — has invested a little over five million dollars. That is less than one percent of ~~our~~ what our European and Japanese competitors have invested. In recognition of this situation, a number of proposals to counteract the European and Japanese initiatives have been put forward by leaders in American industry and government. It is these proposals that the Congressional Budget Office report written by Philip Webre may appear to some readers to discredit.

Mr. Webre appears to have accepted the mistaken, but oft-repeated, view that high-resolution systems are important only to television sets, and since the manufacture of television sets *per se* is not important, HDTV will have no significant effect on American industry — a double error.

HDTV Is not Just about TV!

It would have been more fruitful to question the premises rather than to extrapolate misleading data to an even more misleading set of conclusions. The CBO effort should serve as a warning to others studying high-resolution systems not to proceed thoughtlessly, but to carefully assess the complexity of the real market sectors. For the US Government, the goal must be to design a response appropriate to American research and industrial strengths as a means to revitalize the US electronics base — a base that is rapidly eroding.

Webre does ask, but does not satisfactorily answer, the three basic questions concerning the relationship of high-resolution systems to end markets:

1) **How large is the end market?**

2) **What are the linkages to related industries?**

3) **What is the proper role of government?**

The size of the market.

Let's consider the size of the market. First, there is more than one market; Webre misses this completely. Webre cites three studies which agree that the future entertainment market *alone* will be quite large — roughly ten billion dollars (in 1988 dollars). That total for the future market is nearly *half* of today's entire consumer electronics market. These are large and significant numbers. I am quite comfortable with these projections.

The three studies cited differ principally with respect to *when* this market growth will occur. Most bullish was the Electronics Industries Association. Most conservative was the American Electronics Association, which projected essentially the same market, but with a ten-year lag. The correct time frame will depend upon the pace of technological progress; this is particularly hard to predict accurately. It is what a successful manufacturer seeks to control.

Webre cites an important study performed by MIT at its Audience Research Facility in 1987. Neither Webre nor those who have attempted to use the MIT study to demonstrate that there is no demand for HDTV have understood what MIT found — they have simply missed the point.

The MIT study tested the prototype Japanese NHK high-resolution systems and found that this system had not yet advanced to the point where consumers were interested. Little has changed since the study was done: what is still needed to stimulate the HDTV market are larger and brighter high-resolution displays. Such displays must have only modest cost differentials beyond that of existing TV sets.

This raises a very important question not adequately addressed in the Webre report: just what *is* the nature of consumer demand for HDTV. Let me be very clear about this because there has been considerable misinterpretation of the MIT results. The study does *not* conclude that there is *no* demand for HDTV. It concludes that there is *limited demand for expensive, relatively small cathode-ray-tube displays as judged in normal home-viewing conditions.* This research and new work currently under way concludes that whomever wants to enter the high-resolution marketplace has a special opportunity, not a limited marketplace. These studies find that the Japanese technology shown so far is not optimally designed. The US has an opportunity to leapfrog the foreign competition by introducing larger, and less expensive displays — and much higher levels of resolution.

DARPA's recent initiative focussing on advanced digital display technology was very well conceived in view of the conclusions of the MIT study. This program has established that such displays are technologically feasible, and can leapfrog the inadequate NHK analog displays. Digital high-resolution displays have multiple uses, many of them immediate and highly valuable, as I will discuss next.

It is understandable that the three demand studies cited by Webre have concentrated only on home entertainment. At the time those studies were made, the principal public discussion of high-resolution systems was its potential utility for future entertainment TV. So, HDTV was conceived only in terms of a straightforward extrapolation of today's television, but with some more lines on a screen and maybe better sound. The impact of the MIT study which shook the proponents of "simple" HDTV took awhile to sink in, and the term "high-resolution systems" had not yet even been coined.

Multiple uses for high resolution

We now recognize that high resolutions systems include a broad range of multiple-use, *very* high-definition displays which have begun to appear in military, industrial, medical, educational, and other applications, as well as for entertainment. Even for entertainment, high-resolution imaging has applications beyond the home — in movie theaters, as billboards, and for other environments where extremely large displays will be employed. And high prices are justified at this stage of development.

One illustrative example of the potential size of the non-entertainment market is the recently awarded FAA contract to a *foreign* supplier for high-resolution displays to modernize the US air traffic control system within the next few years. This contract will be for up to ten thousand — *ten thousand* — 2000-line monitors! MIT has several of these monitors for high-resolution imaging research, and they cost roughly forty thousand dollars apiece. The total amount to be spent for these monitors, and related electronics such as memory buffers and drivers, has not been released by the FAA, in testimony to this Congress it has been estimated the ceiling may exceed a billion dollars over the lifetime of the contract — *over a billion dollars!*

Even a nominal ten percent profit margin on just this single award is comparable to the funds currently being discussed for US HDTV R&D by Congress. The industrial, educational, military, telecommunications, and other high-resolution systems markets are collectively huge and deserve proper analysis. The major reason non-entertainment uses have been ignored by these three studies, and the Congressional Budget Office summary, is that no one has yet adequately explored this subject.

Another way to look at this is that a government investment of one hundred million dollars in basic multiple-use R&D would represent one percent of the annual market for high-resolution technology. Even if the forecasts cited in Webre's report are off by a factor of two, then it would be two percent of the annual market. The potential gains for the U.S. far out-distance the modest investment needed to encourage American industry to enter these huge markets.

Linkages

The next issue beyond market size is that of linkages between high resolution system technology and other industrial sectors. The fundamental question here is whether the value of a market, such as HDTV receivers, is simply proportional to its projected sales, as is contended in the Webre report, or whether its value is greater, just as the value of any link in a chain can approach the value of the entire chain. I believe that high-resolution technology is a vital element for the U.S.

electronics manufacturing base and the associated technology "food chain."

Loss of this link could, given current trends, cost the nation the entire chain — its entire electronics base!

At a recent workshop of the United States Activities Board of the Institute for Electrical and Electronics Engineers — the largest association of engineers in the U.S. — it was stated that high resolution systems development will be critical to computer, telecommunication, consumer electronics, industrial, and other important industry sectors.[1] (I request permission to submit the entire report for the record.) The figure attached from that report illustrates the electronics food chain concept.

How do these linkages manifest themselves? In several ways: First, as suggested by the FAA example, a company which has developed a non-entertainment application clearly will be better positioned both technologically, and economically, to succeed in entertainment markets. The next stage in non-entertainment markets is low-cost manufacture of reliable products. For example low-cost FAX has followed high-end xerographic machines. Conversely, firms which have mastered high-resolution system technology for the consumer market will be better positioned for the next stage — success in consumer VCRs has permitted the Japanese to dominate production video systems. Related to this is the simple fact that many aspects of computer and television technology are increasingly merging.

In this light, it is clear what Mr. Webre has written about computer architecture is not in accordance with the facts about that technology. In his statements about PCs and their relationship to high-resolution systems, he confuses the capability of computing systems transparently to run software with that of their input/output functions. For example, virtually all IBM PC compatible laptops are made overseas yet run PC software just like the desktop IBM PCs and clones. The software appears to the user to be transparent. Adding a high-resolution display (and indeed almost all displays already on PCs are of greater resolution and quality than the displays in today's TV sets), does not make the software incompatible.

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[1] IEEE, U.S. Activities Board, "Workshop on Creation of Government/Industry Partnerships through the Formation of American Technology Corporations," National Research Council, Feb. 13-14, 1989, Washington, DC.

Any new output functions could be handled quite well by the insertion of a high-resolution interface card plugged into the motherboard. And to further emphasize the seriousness of this misunderstanding of computer peripherals, most displays, the majority of printers (especially laser printers), and virtually all fax machines, are made by foreign manufacturers today. In the last few years, the PC industry has already become heavily dominated by foreign firms. This point is critical to Mr. Webre's contention that there is no linkage between computers and TV markets.

Whittling away at segments of an industry is not a new story. Take this quote from a story about the introduction of digital audio tape machines in last week's *New York Times*, which I request permission to append for the record:

> "Piece by piece, you [the U.S.] stopped working on the small technologies that add up into big ones," a senior executive of one large Japanese electronics company, who declined to be identified said today. "Now a billion-dollar market is in sight and people are starting to figure out that you pay a price for those little technologies."[2]

More ominous consequences of linkages could arise. For example, suppose large *foreign vertically-integrated producers* of high-resolution displays compete with US assemblers of high-resolution television receivers. And suppose further that the US firms have no choice but to purchase those displays from their foreign, vertically-integrated competitors since the foreign firms are the sole suppliers. Since displays constitute roughly half of end-product content, a small price increase in displays by the integrated foreign producers could eliminate profitability for the US manufacturer; this is not inconceivable, given the increase in price of DRAMS by of a factor-of-*four* when falling prices was expected due to the learning curve. Recently Japanese firms were charging roughly three times as much for DRAMS outside of Japan as they were at home. The mere existence of such capability could motivate US manufacturers to leave (or not to enter) an end product market.

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[2] "For Digital Audio Tape, the Profits will be in Yen," *The New York Times*, July 27, 1989, p. D10. Article attached.

A further, even more frightening consequence of linkage that must be explored is what may happen to the American consumer if the content of TV or computer software were controlled by the same foreign source as the pace of introduction of high-resolution equipment. This question is extremely complex, but early results of such vertical integration have not been terribly encouraging for the US.

A foreign, vertically-integrated high-resolution systems industry, leading in one or more critical technologies, can influence the profitability of US firms not only through price, but also through allocation practices, and control of access to the latest and best technologies.

In summary, I believe that since the linkage issues have been underexplored, their impacts have been underestimated in Webre's report. Yet linkages are extremely important.

The role of government

Finally, there is the issue of the proper role for government in monitoring and promoting the health and independence of US industries in general, and in high-resolution systems in particular. Two recent IEEE workshops have reached broad consensus that private-public cooperation can be enormously fruitful, and would be extremely helpful to the US, not only in establishment of a US high-resolution systems capability, but also to the health of the entire US electronics industry.

Although development of high-resolution systems is a recent issue, there is extensive historical precedent for US industry-government cooperation. One could begin with the growth of railroad infrastructure, which opened up our continent in the nineteenth century. A closely related example to HDTV is the creation of the Radio Corporation of America by the US Navy after World War I, which contributed significantly to US leadership in consumer and military electronics for decades (I request permission to submit a memo I wrote on RCA for the record). The development of RADAR and affiliated military electronics, coordinated by MIT during World War II, is another example of strong industry-government cooperation that put the US far ahead of other countries for decades. The formation of COMSAT by Congress established the US as the world leader in satellite communications. In view of the twentieth anniversary of the moon landing we must also mention a final example — the Apollo program.

An absence of effective cooperation in recent decades between the private and public sectors for commercial and industrial research, development and manufacturing, I believe, has contributed to our loss of international competitiveness in certain key industrial areas. This is the subject of an excellent book by the MIT Commission on Industrial Productivity, entitled "Made in America," which I recommend to all the members of this panel. An excerpt published last month in Scientific American is appended and submitted for the record.

I am delighted that this committee is now focusing so much attention on this critical problem.

THE NEW YORK TIMES, THURSDAY, JULY 27, 1989

For Digital Audio Tape, the Profits Will Be in Yen

By DAVID E. SANGER

Special to The New York Times

News Analysis

TOKYO, July 26 — When the next generation of home-recording technology, digital audio tape, makes its American debut next year, it will provide another example of the price the United States is paying for its retreat from the consumer electronics industry.

At least initially, all of the machines will come from Japan. They will be sold in the United States under an agreement, scheduled to be announced this week, between electronics manufacturers and record companies that had opposed the technology for years because they feared it would increase the pirating of copyrighted recordings.

While the agreement is a big victory for consumers, who will be able to make tape recordings with the distortion-free quality of compact disks, it is also brimming with uncomfortable lessons about the state of American competition with Japan.

Surprisingly, Japan's dominance has little to do with superior technology. The fundamentals of digital audio tape have not changed since the early 1980's, when Japanese makers first showed the machines at trade shows. The problem is manufacturing. The innards of digital audio tape machines are jammed with technologies that the United States stopped making, one by one, starting with its departure from the tape recorder business 20 years ago.

'You Pay a Price'

"Piece by piece, you stopped working on the small technologies that add up into big ones," a senior executive of one large Japanese electronics company, who declined to be identified, said today. "Now a billion-dollar market is in sight and people are starting to figure out that you pay a price for those little technologies."

Many American technology experts here have a sense that they have seen all this before, in videocassette recorders, fax machines and cameras. "The U.S. has fewer and fewer markets it can afford to ignore," said John Stern, who heads an office here for the American electronics industry. "And in a lot of high-technology products we may be stronger, but we are under attack."

No one yet knows how big a loss the digital audio tape market will prove to be for American industry. Early efforts to market the machines in Japan have failed; last year, only about 40,000 machines were sold.

Part of the reason for the slow sales, especially in a country that takes quickly to new technologies, is price. Starting at about $900, and moving up quickly to $2,500, the machines are still very expensive, though the price should drop quickly with higher production volume.

U.S. industry pays a price for abandoning technologies.

Abandoning Cassette Recorders

Digital audio tape's origins are not very high-tech, and go back to the days when the United States dominated the market for cassette tape recorders. Many American electronics companies, faced with a "make or buy" decision to obtain the recorders inexpensively, chose to buy them from Japan. At the time, it seemed a prudent, cost-effective decision.

But ceasing to make the machines also meant an end to efforts to miniaturize them. An important element of that miniaturization was designing the kind of chips used in small recorders like Sony's popular Walkmans and other electronic goods, and the mechanical and electronic functions of small video camcorders.

Other technologies — most of them never attempted by American manufacturers — can also be found in digital audio tape machines. By the time compact disks came out, offering a chance for distortion-free digital recordings, there were precious few American consumer electronics companies left.

None of the advanced technology used in digital audio tape machines is beyond American reach, but all of it requires enormous investment and a step-by-step commitment to manufacturing. "It is not the kind of thing that you can jump back into easily," Mr. Stern said, adding that to his knowledge no American companies have expressed interest in making digital audio tape recorders.

Beating Ourselves at the Game

MADE IN AMERICA
Regaining the Productive Edge.
By Michael L. Dertouzos, Richard K. Lester,
Robert M. Solow and the Massachusetts Institute of
Technology Commission on Industrial Productivity.
344 pp. Cambridge, Mass.:
The MIT Press. $17.95.

By Alice Kessler-Harris

HALFWAY through reading this rich and challenging book, I started to make a list of key words and phrases that recur in its pages. They seem to fall into positive and negative categories. Words like "loyalty," "trust," "cooperation," "flexibility" and "linkages" describe corporate activity that the authors value. "Competition," "standardization," "secrecy" and "adversarial relationships" are attached to behavior that the authors view with skepticism. But though the use of language indicates that the icons of American capitalism are under scrutiny, "Made in America" offers a basically optimistic perception of America's industrial future.

The paradox and its resolution are twin products of the book's conception. In 1986, Paul Gray, the president of the Massachusetts Institute of Technology, put together a commission of 16 distinguished faculty members to "identify what happened to U.S. industrial performance and what we and others might do to help improve the situation." The 16, among them experts in technology, economics, management, organization and political science, examined eight basic industries. Because they were all academics, they examined the participation of their own institution in the training of managers and workers. The result is a scathingly critical assessment of many aspects of America's industrial behavior, informed by a profound faith in our capacity to alter entrenched values.

Like others who have explored the problems of America's industrial decline in the past decade, these commission members accept that the decline of productivity is a product of a complex array of macroeconomic factors — the tax system, the Government deficit, monetary policy — over which industries have little control. But the authors believe that these provide only partial explanation. In the long run, they argue, the solutions will focus on manufacturing, where Americans must address what the commission calls "systematic and pervasive ills" that can only be remedied by changing the way business is practiced. In the end, they suggest, the real weaknesses in the economy lie in "the way people cooperate, manage, and organize themselves, as well as the ways they use technology, learn a new job, and interact with government."

Americans do these things badly, the authors assert. Rooted in a technology that relies on mass production and standarization and bounded by a parochialism that insists that what we want must be suitable for all the world, our industrial enterprise is caught in a time warp. Managers cannot plan effectively for the future because they are wedded to high returns from short-term investments. Industry leads in basic research, but fails to exploit commercial applications. Government and industry work at cross-purposes. Workers do not have the skills to contribute effectively to the manufacturing process. These powerful indictments and others rest on conclusions that grow out of the experiences of particular United States industries compared with those of Japan and Western Europe.

The comparisons touch the heart of the social philosophies that guide us. Driven by the need for high profits and quick returns, American managers shy away from long-term planning and from investment strategies that might have slow pay-back periods. Wedded to a belief in size, business tends to seek the largest markets rather than searching out many profitable niches within the marketplace. With little faith in cooperation, corporations develop antagonistic relationships with their unions, their workers, their suppliers and even with other divisions within a company. Secrecy governs most aspects of product development and leads to a long, slow and cumbersome period of product design. The competitive spirit negates possibilities for agreements among companies that might produce innovative strategies.

In contrast, Japan's industrial success, and to some extent that of Western Europe, is built on a spirit that reflects a different set of values. Committed to cooperation, the Japanese have developed effective ties to suppliers and, in the marketplace, have formed alliances that allow for participation, including consumer testing, in all phases of design development. Managers who are able to accept a longer pay-back period and who count customer loyalty as well as profits as part of their gain have far more flexibility in planning and product development. Loyalty by and toward the work force has encouraged widespread technological innovation inspired from the shop floor. The search not for the largest market share but for niches within the market has allowed the Japanese to create a flexible technology and a responsive industrial capacity. The tangible gains are evident in the absence of adversarial relationships at every link in the industrial chain.

In the context of these powerful underlying forces, the recommendations offered here seem not to touch the central issues. They involve largely behavioral changes in the way that managers operate, in the uses of technology and in the interaction of business and government. But the single most important set of recommendations, stemming perhaps from the make-up of the commission, is directed toward education: managers need greater exposure to, and empathy with, other cultures; workers need more basic skills; education must be lifelong; institutions like M.I.T. need to re-evaluate their requirements for studying other cultures, and so on. This is good advice, but it speaks to the structural and institutional aspects of education and leaves begging the deeper questions that explore how those changes would relate to American society and culture.

The commission espouses values antithetical to those historically credited with the success of American capitalism. Yet the authors do not ask how cooperative work and business relationships are to be built on the success-oriented and self-interested belief system that drives a consumer society. What they seem to suggest is a silent revolution that would affect business ethics, schools and family life. But there is no suggestion about how this transition would take place. This omission in a study otherwise so bravely iconoclastic may have been an inadvertent result of the commission's failure to include cultural experts among its members — no philosopher, no historian, no one whose purpose might have been to think about the meaning of social values.

The absence of this level of inquiry enables the authors to conclude their persuasive critique of American industry with an optimistic prognosis. They cite so-called best-practice businesses that have adopted some of the policies recommended and thus can serve as models and compete successfully in world markets. If the authors are right, then American industry will once again become the engine of a thriving economy. If our industry cannot do that, then we may have to explore some of the larger questions "Made in America" so effectively raises.

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Toward a New Industrial America

A "bottom-up" study of U.S. industrial performance—from the factory floor to the corporate boardroom—by a distinguished group of experts reveals worrisome weaknesses but also encouraging signs of vitality

by Suzanne Berger, Michael L. Dertouzos, Richard K. Lester, Robert M. Solow and Lester C. Thurow

The U.S. economy is a perplexing mix of strengths and weaknesses. It is now in the seventh year of the longest peacetime expansion in this century. Since the early 1980's large numbers of new jobs have been created, and both unemployment and inflation have remained low. American exports have recently surged (helped by a decline in the exchange value of the dollar), and in late 1988 American factories were operating at close to full capacity.

On the negative side, the trade deficit remains formidable (although it is beginning to shrink). In 1988 the U.S. bought about $120 billion more goods and services from other countries than it could sell overseas. The U.S. automobile and steel industries, which once dominated world commerce, have lost market share both at home and abroad, and newer industries are also struggling. The American presence in the consumer-electronics market, for example, has all but disappeared.

There are other disturbing signs that American industry as a whole is not producing as well as it ought to produce or as well as the industries of other nations have learned to produce. Growth in productivity, a crucial indicator of industrial performance, has averaged only slightly more than 1 percent per year since the early 1970's. Productivity has grown more rapidly in several Western European and Asian nations, and U.S. firms are increasingly perceived to be doing poorly in comparison with their foreign competitors in such key aspects as the cost and quality of their products as well as the speed with which new products are brought to market. In many new fields with broad commercial applications, such as advanced materials and semiconductors, America's best technology may already have been surpassed.

In spite of such disquieting developments, some observers maintain that there is nothing fundamentally wrong with American industry itself. The trade deficit, in this view, is the result not of intrinsic deficiencies in industrial performance but rather of such macroeconomic factors as natural differences in rates of economic growth among countries, fluctuations in currency-exchange rates and the enormous U.S. budget deficit. Then, too, the rise and fall of industries is said to be a normal part of economic evolution; at any given time a certain number of industries are sure to be in decline while others are growing.

Yet if the unfavorable trends in industrial performance are real (and we believe they are), then the U.S. has reason to worry. Americans must produce well if Americans are to live well. The sluggish growth in U.S. productivity is barely sufficient to sustain an improvement in the nation's standard of living. (Real wage rates have in fact hardly increased since the early 1970's.) That, in itself, would be of concern regardless of what is happening in the rest of the world. As it is, the more dynamic productivity performance of other countries is also resulting in a relative decline in the U.S. standard of living. Moreover, because political and military power depend ultimately on economic vitality, weaknesses in the U.S. production system will inevitably raise doubts about the nation's ability to retain its influence and standing in the world at large.

Late in 1986 the Massachusetts Institute of Technology established the Commission on Industrial Productivity (with funding from the Sloan and Hewlett foundations) to determine whether there actually are pervasive weaknesses in U.S. industrial practices and, if so, to identify their causes and formulate a set of recommendations to counter them. Unlike many observers of contemporary U.S. industry, the commission did not view the problem entirely in macroeconomic terms. We believed that we could best contribute to the understanding of the problem by focusing on the

SUZANNE BERGER, MICHAEL L. DERTOUZOS, RICHARD K. LESTER, ROBERT M. SOLOW and LESTER C. THUROW were among the 16 faculty members of the Massachusetts Institute of Technology who formed the M.I.T. Commission on Industrial Productivity. Berger is professor in the political science department, which she also heads. Dertouzos, who was chairman of the commission, is professor of electrical engineering and computer science; he is also director of the M.I.T. Laboratory for Computer Science. Lester is professor of nuclear engineering and served as the commission's executive director. Solow, who was the commission's vice-chairman, is institute professor in the department of economics. He is the recipient of the 1987 Nobel prize in economics. Thurow is professor of economics and management and dean of the M.I.T. Sloan School of Management.

nation's production system: the organizations, the plants, the equipment and the people—from factory workers to senior executives—that combine to conceive, design, develop, produce, market and deliver products.

In keeping with this "bottom-up" approach, the commission began its task by dividing into eight teams, each of which would examine in detail one of eight manufacturing industries: automobiles; chemicals; commercial aircraft; consumer electronics; machine tools; semiconductors, computers and copiers; steel; and textiles. These industries combined account for 28 percent of U.S. manufacturing output and about half of the total volume of manufactured goods traded by the U.S. (exports and imports). American firms in each industry were evaluated for what we have come to call productive performance: their efficiency, product quality, innovativeness and adaptability, as well as the speed with which they put new products on the market. Such factors are not explicitly captured in conventional measures of industrial productivity. Altogether, the commission's teams visited more than 200 companies and 150 plant sites and conducted nearly 550 interviews in the U.S., Europe and Japan.

In choosing to focus on the production system itself, we did not underestimate the importance of the macroeconomic factors that regulate the economy in the large; on the contrary, we could not avoid observing their manifestations time and again as the teams proceeded with their work. It is clear that the nation's productive performance problems will not be solved without some improvement in the economic environment. The reason is that investment—meant here broadly to include not only new plants, equipment and public works but also education, training and research and development—is crucial for productivity, and the economic environment largely determines the level of a nation's investment. Indeed, we believe that the highest priority of U.S. economic policy must be to reduce the huge federal budget deficit, which saps the savings from which investment funds are drawn.

Nevertheless, after two years of study, it seems clear to us that current economic conditions ~~do~~ not fully explain the deficiencies in U.S. industrial performance, nor will macroeconomic policy changes suffice to cure them. The relation of poor product quality to U.S. interest rates and tax policies, for example, seems at best tenuous. The economic environment also does not directly affect the speed with which firms identify and respond to changes in the market and to new technological possibilities. Finally, macroeconomics cannot adequately explain why some U.S. businesses thrive in the very same sectors where others are failing, nor why Japanese manufacturing plants in the U.S. have often achieved better results than comparable American plants.

By looking at what actually takes place in industry—from the shop floor to the boardroom—the commission was able to observe recurring patterns of behavior and to draw certain conclusions about the most important micro-level factors that have adversely affected U.S. industrial performance. To do so the commission worked much like a jury: we assessed the large mass of detailed, diverse and sometimes contradictory evidence that the study teams had collected, ultimately reaching a verdict.

The verdict is that U.S. industry indeed shows systematic weaknesses that are hampering the ability of many firms to adapt to a changing international business environment. In particular, the commission observed six such weaknesses: outdated strategies; neglect of human resources; failures of cooperation; technological weaknesses in development and production; government and industry working at cross-purposes; and short time horizons.

The industry studies revealed two types of outdated strategies that are impeding industrial progress today: an overemphasis on mass production of standard commodity goods and an economic and technological parochialism. Both are holdovers from the unique economic environment that prevailed after World War II. For decades after the war U.S. industry was able to flourish by mass-producing undifferentiated goods principally for its own markets, which were large, unified and familiar. Because firms in most other countries had to rebuild in economies devastated by the war, they could mount no significant competition and were largely ignored by U.S. industry.

Not only did U.S. producers sell their wares primarily to the domestic market, they also drew their technical expertise almost exclusively from U.S. factories and laboratories. Such technological parochialism blinded Americans to the growing strength of scientific and technological innovation abroad and hence to the possibility of adapting foreign discoveries. In the 1950's and 1960's, for example, American steel producers lagged behind Japanese and European steelmakers in adopting such new process technologies as the basic oxygen furnace; later they were again slow to adopt continuous casters and such quality-enhancing technologies as vacuum degassing and oxygen injection. The critical error in many of these cases was the failure to recognize the worth of someone else's innovation.

The American industry of the 1950's and 1960's pursued flexibility by hiring and firing workers who had limited skills rather than by relying on multiskilled workers. Worker responsibility and input progressively narrowed, and management tended to treat workers as a cost to be controlled, not as an asset to be developed.

Training practices in the U.S. have been consistent with that strategy. Workers often receive limited training while on the job; typically it amounts to watching a colleague at work. Even in firms offering organized training programs, in-plant training is usually short and highly focused on transmitting specific narrow skills for immediate application. In other countries we observed a greater inclination to regard firms as learning institutions, where—through education and training—employees can develop breadth and flexibility in their skills and also acquire a willingness to learn new skills over the long term. In a system based on mass production of standard goods, where cost matters more than quality, the neglect of human resources by companies may have been compatible with good economic performance; today it appears as a major part of the U.S.'s productivity problem.

The neglect of human resources in the U.S. actually begins long before young Americans enter the work force. It is in primary and secondary school that they learn the fundamental skills they will apply throughout life: reading, writing and problem solving. Yet cross-national research on educational achievement shows American children falling behind children in other societies in mathematics, science and language attainment at an early age and falling farther behind as they progress through the school years. The school system—from kindergarten through high school—is leaving large numbers of its graduates without basic skills. Unless the nation begins to remedy these inadequacies in education, real progress in improving the U.S.'s productive performance will remain elusive.

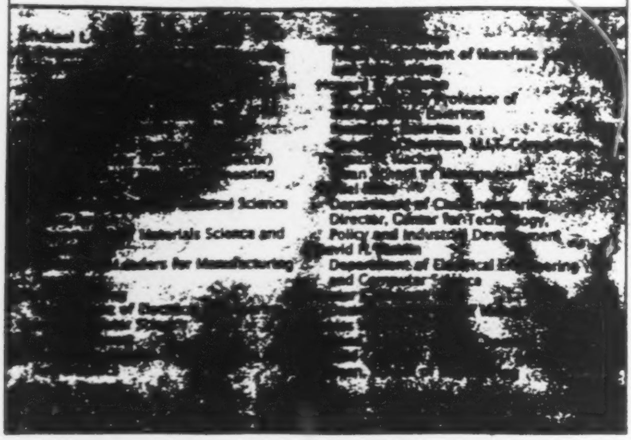
The third recurring weakness of the U.S. production system that emerged from our industry studies is a widespread failure of cooperation within and among companies. In many U.S. firms communication and coordination among departments is often inhibited by steep hierarchical ladders and organizational walls. In addition, labor and management continue to expend valuable resources and energies battling over union organizing.

Suppliers and even customers have also been kept at arm's length by the management of many U.S. companies, in spite of the fact that such vertical linkages can be conduits not only for raw materials and finished products but also for technological innovations and other developments that enhance productivity. These companies are reluctant to share designs, technologies and strategies with either their customers or their suppliers for fear that proprietary information will leak to competitors. Yet by keeping that kind of information to itself, a firm misses the chance to work with its suppliers and customers to improve the products it sells and buys. A similar lack of horizontal linkages—cooperative relations between firms in the same industry segment—has led to a dearth of joint projects in such areas as the setting of common standards and industrial research and development, even when they might have been permitted under the law.

Notwithstanding its spotty performance in the global market in recent years, the U.S. remains the world leader in basic research.

FIRST COMMERCIAL VIDEOTAPE RECORDER was made by the Ampex Corporation in Redwood City, Calif., but no U.S. firms were willing or able to devote the resources to bring unit costs down for sale to retail customers. Ampex concentrated on high-price, high-performance systems; other U.S. firms abandoned the field altogether. Japanese companies had the financial stamina to sustain low returns on investments while perfecting designs and manufacturing processes. The result is that the Japanese now dominate the consumer video-recording market. Moreover, by capitalizing on the profits, technology and economies of mass production built up in that market, they have begun to encroach on the upscale market as well.

THE M.I.T. COMMISSION ON INDUSTRIAL PRODUCTIVITY


Materials Science and
Leaders for Manufacturing
Director, Center for Technology, Policy and Industrial Development
David H. Staelin
Department of Electrical Engineering and Computer Science

MEMBERS of the Commission on Industrial Productivity were drawn from the faculty of the Massachusetts Institute of Technology. The interdisciplinary group included economists, technologists and experts on organization, management and politics.

Ironically that outstanding success may have diverted attention from "downstream" technological skills in product and process development and production that become progressively more important as new concepts proceed down the path from the laboratory to the marketplace. Simply put, many U.S. firms have been outperformed in the design and manufacture of reliable, high-quality products.

A survey conducted by the International Motor Vehicle Program (IMVP) at M.I.T. found that, despite recent gains, the number of defects reported in the first three months of use was still almost twice as high for cars produced in American plants in 1986 and 1987 as for those from Japanese plants. The commission's automobile study team also learned that American car builders have recently been taking about five years to carry a new design from the conceptual stage to commercial introduction. In contrast, Japanese manufacturers complete the cycle in three and a half years.

Some of the responsibility for the persistent failure to convert technologies quickly into viable, high-quality products lies in the American system of engineering education, which has deemphasized product realization and process engineering since World War II. The professional norms of the American engineering community also assign rather low priority to such essential downstream engineering functions as the testing of product designs, manufacturing and product and process improvements.

Other aspects of the problem can be found in certain practices followed by U.S. industry. For one, many American companies simply do not devote enough attention to the manufacturing process. In a recent comparative study of industrial research and development in Japan and the U.S., Edwin Mansfield of the University of Pennsylvania found that U.S. companies are still devoting only a third of their R&D expenditures to the improvement of process technology; the other two thirds is allocated to the development of new and improved products. In Japan those proportions in R&D expenditures are reversed.

Many U.S. companies also fail to coordinate product design and the manufacturing process. It has been standard practice for design engineers to end their involvement with a new product once they have conceived its design. They hand over the design to manufacturing engineers, who are then supposed to come up with a process for the product's manufacture. This compartmentalization of tasks has led to serious problems. Product-design groups often neglect manufacturing considerations, making it harder to come up with a manufacturing process.

The Proprinter project of the International Business Machines Corporation is an impressive example of what can be achieved when product designers are brought together with manufacturing engineers and research scientists. Charged with designing a new computer printer that has fewer component parts and no springs or screws (which increase assembly time and decrease reliability), a multidisciplinary IBM design team came up with a product having 60 percent fewer parts than its predecessor. (Ironically because an individual assembly worker could put the printer together in three and a half minutes, the highly automated and expensive assembly plant that had been built to make it was largely rendered superfluous.)

Multifunctional design teams and an orientation toward simplicity and quality at the design stage have been a long-standing fixture of Japanese industry and have contributed to its comparative advantages in quality and productivity. The IMVP survey showed that Japanese-designed automobiles retain their quality advantage even when they are assembled in American factories, which implies that the Japanese automotive engineers had incorporated quality-enhancing features into the design itself.

American companies also have often lagged behind their overseas competitors in exploiting the potential for continual improvement in the quality and reliability of products and processes. The cumulative effect of successive incremental improvements in and modifications of established products and processes can be very large; it may even outpace efforts to achieve technological breakthroughs.

The federal government deserves part of the blame as well for the technological weaknesses in development and production. Whereas the governments of most other industrial nations have purposefully promoted research and technology for economic development, U.S. policy for science and technology has traditionally focused on basic research. The commercial development and application of new technologies have for the most part been considered to be the responsibility of the private sector.

To be sure, the Department of Defense, the National Aeronautics and Space Administration and other federal agencies have invested heavily in technology development. Indeed, about 46 percent of all U.S. research and development is sponsored by the Government. Those expenditures are usually in the areas of defense and space activities or in other specific Governmental missions, however. In such cases commercial applications of the resulting technology are considered secondarily, if at all. Furthermore, there are indications that defense R&D, which accounts for almost two thirds of all federal R&D spending, is becoming less relevant to the needs of the civilian market.

More generally the lack of a common agenda between government and industry has produced negative effects across broad stretches of the U.S. economy. Some observers, for instance, have blamed the collapse of the consumer-electronics industry in part on the federal government's failure to enact or implement tariffs and import quotas as well as to amend or enforce antidumping and antitrust laws. Yet while some see the problem as too little government support for key industries, others see it as too much government support for inefficient producers.

The evidence gathered from the commission's industry studies was similarly mixed regarding the charge that too much government intervention, particularly in regulating the environment and occupational safety, has put U.S. companies at a disadvantage in relation to foreign competitors. Where problems have arisen, the fault tended to lie in the nature of the regulatory process rather than in the strictness of the regulations themselves. Indeed, many European countries as well as Japan now have environmental and occupational-safety laws in many areas that are at least as strict as those in the U.S.

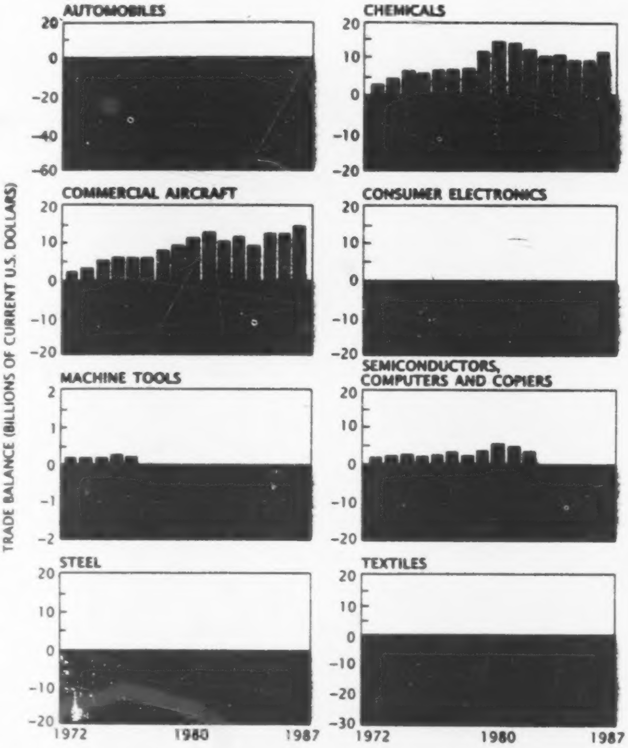
The issue, then, is not simply whether there is too much government or too little. What is clear to the commission, however, is that a lower level of cooperation between government and business exists in the U.S. than it does in the countries of American firms' major foreign competitors and that the frequency with which government and industry find themselves at cross-purposes is a serious obstacle to strategic and organizational change in individual U.S. firms.

American industry has also been handicapped by shrinking time horizons and a growing preoccupation with short-term profits. There have been many recent instances in which U.S. firms have lost market share to overseas competitors despite an early lead in technology or sales, or both. Often these firms effectively cede a potential market by not "sticking to their knitting"; instead, they diversify into activities that are more profitable in the short run.

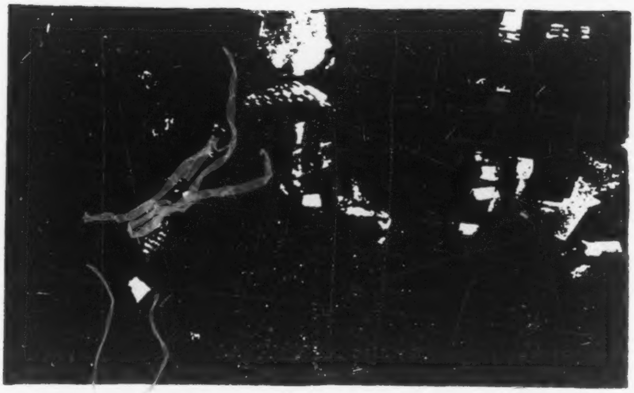
The development of the videocassette recorder provides an exemplary case. Video-recording technology was first developed in the U.S., but the early machines were complex and expensive and suitable only for industrial and professional applications; many years of further development were needed to create low-cost, highly reliable products for the mass-consumer market. No American manufacturer was willing or able to spend the time and money, but several Japanese manufacturers were. The Japanese are now virtually unchallenged as makers of the most important single product in the consumer-electronics market.

Why are U.S. firms less willing than their rivals to live through a period of heavy investment and meager returns in order to build expertise and secure a foothold in a new market? Is it that American managers are incapable of looking as far ahead as their foreign counterparts? Or are they forced by external circumstances to focus on the short term, even though they realize that it is not in their firm's best interest to do so? Or might it be that a short-term focus is actually in the best interest of the firm but not of the U.S. economy as a whole?

Some observers argue that the higher cost of capital in the U.S. compared



BALANCE OF TRADE (the total value of exports less the total value of imports) for the eight key manufacturing industries studied by the commission reflects the industries' general condition in the U.S. A positive balance means that more of an industry's products are sold overseas than are exported to the U.S. by foreign rivals; a negative balance implies the converse. An industry's trade balance is affected by the performance of its firms with respect to product cost and quality, service and the speed of response to new technological and market opportunities. Macroeconomic conditions—particularly currency-exchange rates—can also affect the balance.



NATURE OF U.S. SECURITIES MARKET has contributed to the short time horizons of American businesses. Managers of mutual and pension funds, which own a large and growing share of the capital of U.S. firms, tend to turn over their fund's stockholdings rapidly in an effort to maximize the current value of the investment portfolio. Such a strategy undervalues long-term development and investment policies of U.S. firms.

with its cost in Japan is the overriding reason for the different time horizons of firms in the two countries. Certainly the cost of capital is important, but we think that other factors are also important.

The nature of the institutions that influence the supply of capital may affect investment decisions at least as much as the cost of capital. A large and growing share of the capital of U.S. firms is owned by mutual funds and pension funds, which hold assets in the form of a market basket of securities. The actual equity holders, the clients of the funds, are far removed from managerial decision making. The fund managers also have no long-term loyalty to the corporations in which they invest and have no representation on their boards. (Indeed, legislation prohibits their participation in corporate planning.)

Although some fund managers do invest for the long term, most turn over their stockholdings rapidly in an effort to maximize the current value of their investment portfolio, since this is the main criterion against which their own performance is judged. Firms respond to this financial environment by maximizing their short-term profit in the belief that investment policies oriented toward the long term will be undervalued by the market and thus leave them vulnerable to a take-over.

At the same time senior executives are also motivated to maintain steady growth in earnings by their own profit-related bonus plans and stock options. A chief executive whose compensation is a strong function of his or her company's financial performance in the current year will naturally stress short-term results.

Explanations that cite the cost of capital and the sources of financing all tend to depict corporate managers as victims of circumstance, forced by external conditions into a short-term mind-set. Yet Robert H. Hayes and the late William J. Abernathy of the Harvard Business School have argued that executive ranks have come to be dominated by individuals who know too little about their firm's products, markets and production processes and who rely instead on quantifiable short-term financial criteria. These modern executives are more likely to engage in restructuring to bolster profits than to take risks on technological innovation.

As part of its work the commission sought to find not only patterns of weakness in U.S. industry but also patterns of change that are common to successful U.S. firms—firms that are doing well in the international arena. Indeed, we probably learned as much from what such "best practice" firms are doing right as from what many other U.S. firms are doing wrong.

In particular, we found that successful firms emphasize *simultaneous* improvements in quality, cost and speed of commercialization. Whereas other firms often trade off one dimension of performance against another, only the best companies have made significant improvement in all three. To gauge progress, one common practice among the successful firms is to emphasize competitive benchmarking: comparing the performance of their products and work processes with those of the world leaders. At the Xerox Corporation, for example, quality improved by an order of magnitude over the past decade after the company instituted detailed comparison tests of Xerox copiers and competing Japanese models.

In addition, the best-practice firms we observed are developing closer ties to their customers. These ties enable companies to pick up more detailed signals from the market and thus to respond to different segments of demand. They also increase the likelihood of rapid response to shifts in the market. Even high-volume manufacturers have combined a continuing emphasis on economies of scale with a new flexibility, reflected in shorter production runs, faster product introductions and greater sensitivity to the diverse needs of customers.

Closer and more tightly coordinated relations with suppliers were also observed among the best-practice firms. In some cases, better coordination with suppliers has been achieved through the coercive power of market domination, in others by new forms of cooperation and negotiation. No matter how it comes about, coordination with external firms is crucial in cutting inventories (and thereby costs), in speeding up the flow of products and in reducing defects.

For example, Greenwood Mills, Inc. (a textile company specializing in the production of denim), brought down its inventory radically over two years, even as sales doubled. To achieve those results the company tightened up its own operations and at the same time negotiated new arrangements with suppliers, who now deliver on a just-in-time basis. In exchange, Greenwood Mills halved the number of its suppliers, leaving itself more vulnerable to price hikes but gaining the advantages of closer collaboration.

Most thriving firms in the U.S. have also realized that business strategies based on throwing new hardware at performance problems are unlikely to work. They have instead learned to integrate technology in their manufacturing and marketing strategies and to link them to organizational changes that promote teamwork, training and continuous learning. In the generally depressed domestic apparel industry, firms such as the Model Garment Company and Levi Strauss & Company are succeeding by investing heavily in information technologies that allow them to fill orders very rapidly and reduce inventory levels.

In virtually all successful firms, the trend is toward greater functional integration and lesser organizational stratification, both of which promote quicker product development and increased responsiveness to changing markets. The Ford Motor Company was the first U.S. automobile company to experiment with cross-functional teams to speed the development and introduction of a new model. The product-development team for the Taurus model included representatives from planning, design, engineering, manufacturing and marketing. The specialists worked simultaneously rather than serially.

Flattening steep organizational hierarchies goes hand in hand with dismantling functional barriers. A flatter hierarchy generally enhances organizational flexibility. It also promotes closer relations with customers: a customer with a problem can speak directly with the group that has responsibility for the product instead of having to go through a sales department. In leaner, less hierarchical organizations the number of job categories at each level is reduced, and the responsibilities associated with particular jobs are broadened.

At the Chaparral Steel Company, for instance, there are almost 1,000 employees, and yet there are only four job levels. Production workers are responsible for identifying new technologies, training, meeting with customers and maintaining equipment. Foremen and crews install new equipment. Security guards are trained as emergency medical technicians, and they update computer records while on their shift.

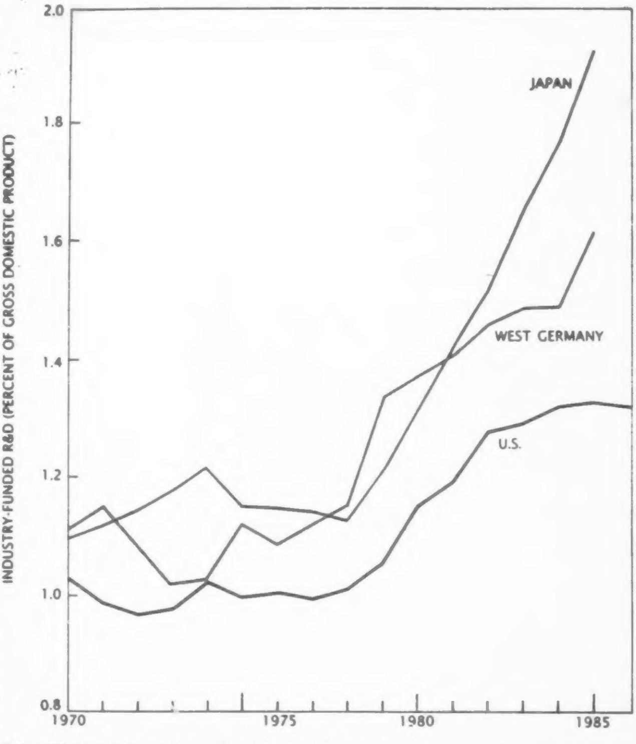
An essential ingredient for greater worker responsibility and commitment is continual training. Large companies such as IBM have the resources to train their own workers. Having lower labor turnover, they also have more incentive to invest in training, because they are more likely to capture the benefits of that investment. Smaller companies do tend to draw more heavily on outside institutions for training, but there is often a major internal component as well.

The Kingsbury Machine Tool Corporation once built dedicated equipment for vehicles; it has since successfully converted to building computer-controlled machines and production lines for flexible manufacturing. Under the old regime the primary demand on the work force was for mechanical skills, but the new product line requires workers with some knowledge of computers. To retrain the employees, the company provided everyone—from janitors to vice presidents—with computers to use at work or at home and offered classes to employees and their families.

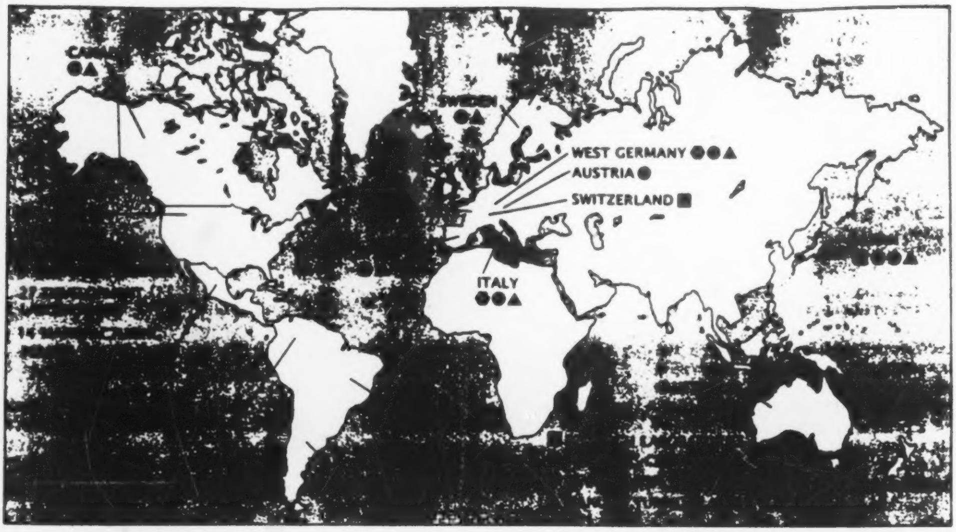
Although an increasing number of American companies are recognizing what it takes to be the best in the world, many U.S. firms have not yet realized that they will have to make far-reaching changes in the way they do business. They will need to adopt new ways of thinking about human resources, new ways of organizing their systems of production and new approaches to the management of technology. What distinguishes the best-practice firms from the others in their industries is that they see these innovations not as independent solutions but as a coherent package. Each change for the better reinforces the others, and the entire organization is affected by them.

Of course, today's best practices will surely not remain the best forever. The nature of industrial competition is changing rapidly, and new challenges will undoubtedly emerge. The commission identified three major and pervasive long-term trends that will have broad implications for the future productive performance of U.S. firms.

First, economic activity will continue to become more international. A company's ownership, location, work force, purchases and sales are all



INDUSTRY-FUNDED RESEARCH AND DEVELOPMENT has grown more slowly in the U.S. than in Japan and West Germany. Total spending on R&D as a percentage of gross domestic product, however, is about the same in the three countries, because the difference in industry-funded R&D is made up in the U.S. by federal funding of R&D.



INCREASING INTERNATIONALIZATION of the U.S. economy has led the International Business Machines Corporation to establish numerous research laboratories, scientific centers, development laboratories and manufacturing plants in foreign countries. Such a geographic distribution helps the corporation remain abreast of technological advances throughout the world. IBM also maintains sales offices in more than 100 countries in order to keep in closer contact with its customers.

spreading beyond the boundaries of the nation in which it originated. A growing number of countries will acquire the capacity to produce and to export sophisticated goods and services. Many of these emerging economies have labor costs even lower than those of Taiwan and South Korea and far lower than those of the U.S., Japan and Europe.

Second, partly because of internationalization and partly because of rising incomes around the world, markets for consumer goods and intermediate goods are becoming more sophisticated. Markets are also becoming more segmented and specialized; not everyone is prepared to accept the same product designs and specifications.

Third, we expect the rapid pace of technological change to continue. Particularly rapid progress seems likely in information technology, materials science and engineering, and biotechnology. Information technology has already permeated nearly every facet of the production of goods and delivery of services, and we expect it to affect the business environment in a number of ways in the future.

The obvious implication of these three trends is that U.S. firms will not be able to compete on the basis of cost alone. The future of U.S. industry lies in specialized, high-quality products; standard commodities will be made in the U.S. only if their production is extraordinarily capital-intensive and technologically advanced. At the same time, competition among U.S., Japanese and European firms in markets for high-value-added products will become increasingly fierce.

Indeed, the convergence of future consumer preferences, market forces and technological opportunities may lead in some industries to the introduction of "totally flexible" production systems. In such systems custom-tailoring of products to the needs and tastes of individual customers will be combined with the power, precision and economy of modern production technology.

In a market economy such as that of the U.S., individual firms have the primary responsibility to correct past problems and find ways to compete successfully in the future. Yet for the U.S. to achieve an economy marked by high productivity growth, all sectors—business, government, labor and educational institutions—will need to work together. Based on its study of current weakness and best practices in American industry, as well as its forecast of long-term trends, the commission believes that five interconnected imperatives should form the core of any such national effort.

First, the U.S. needs to invest more heavily in its future. This means investment not only in tangible factories and machinery but also in research and, above all, in human capital. At the macroeconomic level, as noted earlier, bringing the budget closer into balance should take high priority. In order to encourage firms to develop the necessary outlook for long-term investments, American economic policy should also favor increasing productive investment over private consumption through an approach that combines a more expansionary monetary policy with a fiscal policy that taxes consumption more heavily than savings or investment. Such policies can increase the supply of capital to business. Tax and credit legislation making it harder and more expensive to raise large sums of money for takeovers and buy-outs is additionally needed. Government must also work with industry and academia to ensure not only that investment continues strongly in basic research but also that it expands in the direction of productive manufacturing technologies.

Public resources should be allocated not only to improve the existing economic infrastructure (roads, airports, harbors and the like) but also to invest in new kinds of infrastructure. For example, we think that the time is right for American business and Government to begin developing a national information infrastructure, which would eventually become a network of communication highways as important for tomorrow's business as the current highway network is for today's flow of goods.

The most important investment in the long run is in the nation's schools. A better basic education will be crucial to the technological competence that will be required to raise the productivity of U.S. industry. Without major improvements in primary and secondary schooling, no amount of macroeconomic fine-tuning or technological innovation will yield a rising standard of living.

The second major imperative, closely related to the first, is to develop a new "economic citizenship" in the workplace. The effective use of modern technology will require people to develop their capabilities for planning, judgment, collaboration and the analysis of complex systems. For that reason learning—particularly through on-the-job training programs—will acquire new importance.

Greater employee involvement and responsibility will be needed to absorb the new production technologies. Companies will no longer be able to treat employees like cogs in a big and impersonal machine. If people are asked to give maximum effort and to accept uncertainty and rapid change, they must be full participants in the enterprise rather than expendable commodities. Just as important as job security is a financial stake in the long-term performance of the firm. We see in this combination of technological and organizational change an unprecedented opportunity to make jobs more satisfying and rewarding for workers at all levels of a firm.

Third, the U.S. needs to make a major commitment to mastering the new fundamentals of manufacturing. Manufacturing, as we use the term here, encompasses a great deal more than what happens on a production line. It includes designing and developing products as well as planning, marketing, selling and servicing them. Global competition, changing markets and modern technologies are transforming virtually every phase of the production system.

Managers who are detached from the details of production will lose the competitive battle to managers who know their business intimately. Manufacturability, reliability and low cost should be built into products at the earliest possible stages of design. Innovation must be applied to process development as intensively and creatively as it is now applied to product development. Corporate management and financial institutions must work together to develop indicators that better reflect how well companies are actually doing in developing, producing and marketing their products than do short-term financial measures such as quarterly earnings. New measures might include indicators of quality, productivity, product-development time and time to market.

Fourth, Americans should strive to combine cooperation and individualism. The nation's culture has traditionally emphasized individualism, often at the expense of cooperation. Yet in the best U.S. companies (as in other societies), group solidarity, a feeling of community and a recognition of interdependence have led to important economic advantages.

To this end, steep organizational hierarchies, with their rigidity and compartmentalization, should be replaced with substantially flatter organizational structures that provide incentives for communication and cooperation among different corporate departments. Companies should put less emphasis on legalistic and often adversarial contractual agreements; they should promote business relations based on mutual trust, common goals and the prospect of continuing transactions over the long run. Management must also accept workers and their representatives as legitimate partners in the innovation process. Both individual and group efforts need recognition and reward.

Americans should think of cooperation among economic entities as a way of overcoming the defects of the market, which often undersupplies collective factors essential to economic success. Cooperative efforts can take the form of research consortiums, joint business ventures, partnerships with Government and standard-setting committees. (To be sure, such arrangements might lead producers to combine forces in order to exploit the consumer. Now and in the future, competition from imports will no doubt provide some protection from domestic monopolies. Still, a little vigilance would help too.)

Fifth, to compete successfully in a world that is becoming more international and more competitive, Americans must expand their outlook beyond their own boundaries. They must gain knowledge of other languages, cultures, market customs, tastes, legal systems and regulations; they will need to develop a new set of international sensitivities.

Cost considerations will increasingly dictate whether materials and components are best procured at home or abroad. It follows that not only a company's marketing division but also its purchasing agents and production managers will have to be knowledgeable about global conditions. Shopping internationally should go beyond the buying of raw materials and off-the-shelf products to the adoption of effective practices and technologies—wherever they happen to be found.

Americans need to understand that the world they live in has changed. The effortless economic superiority that the U.S. enjoyed in the aftermath of World War II has gone. Strong economic cultures now exist across both the Atlantic and Pacific oceans. The U.S. has much to learn from the rest of the world. Indeed, the rest of the world will force changes in some of the most cherished American operating procedures and assumptions, if the U.S. is to continue to have a standard of living second to none. What Americans must do is determined decreasingly by what they wish to do and increasingly by the best practices of others.

Implementing these five imperatives will not be easy. In many cases, fundamental changes in attitude will be necessary. Just accepting the need for a sense of common purpose—a shared national goal—may require the biggest attitudinal change of all. The commission believes that if industry, government and the educational system in this country unite in steadfast pursuit of these basic imperatives the next generation of Americans will live in a nation moving into the 21st century with the same dynamism and strength that made it a world leader a generation ago.

FURTHER READING

MADE IN AMERICA: REGAINING THE PRODUCTIVE EDGE. Michael L. Dertouzos, Richard K. Lester, Robert M. Solow and the MIT Commission on Industrial Productivity. The MIT Press, 1989.

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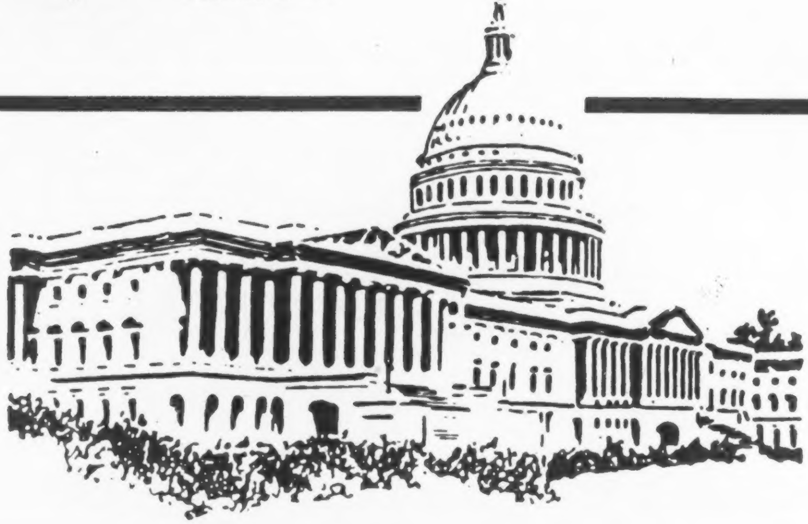

Workshop on Creation of
Government/Industry Partnerships
through the Formation of
American Technology Corporations
February 13-14, 1989
National Research Council
Washington, D.C.

UNITED STATES ACTIVITIES BOARD

ABSTRACT

This workshop, which was broadly attended by about 55 participants from U.S. industry, academia, and government, was held in response to the IEEE-USA Technology Activities Council entity position paper of January 25, 1989, which concerned the urgent need for an immediate national response to significant deterioration in vital U.S. electronics sectors, with an emphasis on high-resolution systems. Working groups on Organizational and Effectiveness Issues, Technology and Manufacturing Capabilities, and Standards and Services met and then reported to plenary sessions where overall consensus was sought. This report summarizes the discussion and conclusions reached in these sessions concerning the creation of government/industry partnerships through formation of American Technology Corporations.

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sponsored by
The Institute of Electrical and Electronics Engineers
United States Activities - Technology Activities Council
(IEEE-USA)

TABLE OF CONTENTS

I. Highlights of Conclusions 3

II. Issues Addressed in Plenary Sessions 4

- A. U.S. Situation Assessment 4
- B. Japanese and European Development Strategies 6
- C. Standards 6
- D. DRAMs 7
- E. Congressional/Governmental Situation 7
- F. Television and Related Future Businesses 8
- G. Relationship Between Manufacturing and R&D 8
- H. Antitrust Issues 8
- I. Participation by Foreign Firms 10
- J. Relative Roles of Industry and Government 10
- K. Implementation of Workshop Recommendations 11

III. Issues Addressed in Working Group A: Organizational and Effectiveness Issues 12

- A. Foreign Participation 12
- B. Local Research and Development and Intellectual Property 12
- C. Profitability, Protection, and Industrial Policy 13
- D. Cost of Capital 13
- E. Market Access and Corporate Strategy 13
- F. Government Purchases 14
- G. Initial Evolution of the HDTV Market 14
- H. Industry-Government Relations 14
- I. Links between Technology and Production 15
- J. Trade 15

IV. Issues Addressed in Working Group B: Standards and Services 16

- A. Agenda 16
- B. Open Architecture Receivers (OAR) 16
- C. Proprietary Technologies and Standards 18
- D. "Friendly Family" of Standards 19
- E. Immediate Standards and Technology Issues 20
- F. Vision Statement 21

V. Issues Addressed in Working Group C: Technology and Manufacturing Capabilities 22

- A. Technology Status 22
- B. Technology Linkages 24
- C. Manufacturing Equipment 24
- D. The DARPA Initiative 24
- E. Business Issues 25
- F. Consortia 25

Appendix: IEEE-USA Entity Position Statement 27

I. Highlights of Conclusions

The Workshop, which was broadly attended by about 55 participants from industry, academia, and government, reached consensus on several points:

- **Survival of the U.S. industrial base in vital electronics sectors is at stake.**
- **Industry-led consortia with government cooperation and support are necessary to address the problem.**
- **Dual-use technologies meeting both civilian and military needs should be developed with participation by both the Department of Defense and Department of Commerce[1].**
- **High-resolution-systems technology and world class manufacturing are key areas for action. Displays and DRAMS are the most critical elements.**
- **The IEEE-USA entity position statement of January 25, 1989 was endorsed (see Appendix A); it further called for such consortia and associated government support to be established this year.**

The Workshop applauded the DARPA[1] initiative in providing seed money for high-resolution systems, which is of historical significance in its recognition that 1) future low-cost military technology is ultimately related to the health of U.S. consumer electronic design and manufacture and 2) that such dual-use activities must also be market-driven. Establishment of competitive U.S. high-resolution systems technology and manufacturing for displays, DRAMs[2], and supporting technologies was particularly recommended.

These industry-led consortia must attract U.S. firms by providing an environment that is economically attractive and that reduces risks to the participants. The government should support these objectives through the following actions:

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[1] For example, by the Defense Advanced Research Projects Agency (DARPA) and the National Institute of Standards and Technology (NIST; the former National Bureau of Standards), respectively.

[2] DRAMs are dynamic random access semiconductor memory devices that are central to current computers, future HDTVs, and other products.

- **Providing financial support for U.S. industry-led consortia,**
- **Recognizing the importance of an hospitable antitrust environment to the attraction of private U.S. capital, and**
- **Equalizing capital costs and risks for U.S. participants relative to foreign competitors in these global markets.**

These consortia must be dedicated to improving the competitiveness of U.S. manufacturing firms and contribute to the revitalization of the U.S. electronics industries. Consistent with these objectives such consortia should be open to participants on a reciprocal basis.

II. Issues Addressed in Plenary Sessions[3]

A. U.S. Situation Assessment

1) Technology

It was felt that the most critical issue is the integrity of the electronics "food chain" (see Figure 1), where this chain extends from critical materials (such as silicon and gallium arsenide) to components, subassemblies, and integrated systems, as well as to the associated research and development for both product and manufacturing processes and equipment. The greatest weakness today is in the lower levels of the food chain, particularly as they relate to low cost world-class manufacturing in volume. "Flexible manufacturing" and "design for manufacturing" were also cited as two key areas of relative weakness. These fundamental weaknesses in manufacturing impact not only consumer electronics but also the related fields of computers, telecommunications, and other industrial sectors dependent upon low cost sophisticated electronic elements.

There was agreement that it is not too late for the U.S. to reenter world consumer electronics markets, for we still retain residual research and development capabilities in this area -- the problem is one of scaling up competitively. Reentry should be centered on emerging technologies rather than those which are obsolescent. In such a reentry Zenith Electronics

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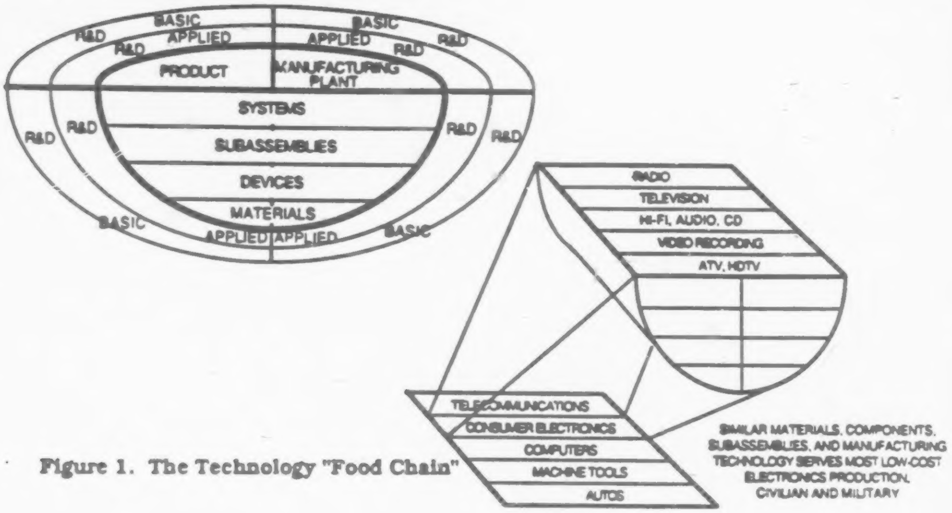
[3] Repetition of IEEE-USA position paper concepts (Appendix A) is omitted here.

Corporation and the SRI David Sarnoff Laboratories are important national assets because they comprise the largest surviving U.S. resources in this area.

TECHNOLOGY/MANUFACTURING LINKAGES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HI-FI, AUDIO, CD
VIDEO RECORDING
ATV, HDTV
TELECOMMUNICATIONS
CONSUMER ELECTRONICS
COMPUTERS
MACHINE TOOLS
AUTOS
SIMILAR MATERIALS, COMPONENTS, SUBASSEMBLIES, AND MANUFACTURING TECHNOLOGY SERVES MOST LOW-COST ELECTRONICS PRODUCTION, CIVILIAN AND MILITARY

Figure 1. The Technology "Food Chain"

2) Economics

The single most important economic issue is industry's need for long term capital at rates comparable to the effective costs of capital for U.S. competitors. The estimated effective costs of such capital for Japanese firms was 3.5%, versus 11% (or more) for U.S. firms. It was felt that this sort of discrepancy, by itself, could systematically foreclose the future for such disadvantaged U.S. manufacturing firms, particularly those firms with the greatest need for such long term investments.

Other aspects of the U.S. macroeconomic environment were felt to be more unchangeable, and Lester Thurow's characterization seemed apt. His recently expressed view is that the U.S. is in a "growth tunnel" where the growth must be held in a narrow range of approximately 3-3.5% per annum. This growth rate is bounded from above by difficulties in attracting adequate capital at acceptable rates to grow more rapidly, and is bounded from below by our need to create a U.S. market for Latin American exports so that these countries can pay their debts; significant default on these debts could conceivably precipitate a banking crisis. These constraints, plus the inertia of present government policies and the lack of a sense of crisis, make continuation of present macroeconomic policies the most likely outcome. The Workshop expressed concern that in this macroeconomic climate the U.S. will continue to lose not only its technological industrial base, but also its ability to recreate that base, unless significant steps are taken. Discussion of some of these steps was one of the purposes of this Workshop.

3) Competitiveness

There was widespread agreement that the present U.S. competitive position in low cost sophisticated electronics has seriously deteriorated, principally during the past decade. It was felt that we still retain, for the moment, an ability to turn this situation around. To do this, however, focus must be placed on corporate investment strategy and financial return. There is a serious need to lower investment risks for U.S. firms. Such concerns about investment strategy were said to be critical, for example, for the more than 25 firms now collaborating with the AEA in the definition of a consortium. The importance of participation by major U.S. corporations was cited, and the belief was expressed that with such participation there would be significant interest by smaller firms as well.

B. Japanese and European Development Strategies

Among the strategies found to be valuable overseas was the tendency to view the technology base as a chain (e.g., "food chain") running from semiconductors through semiconductor manufacturing and into computers and other product lines. Cardinal rules of industrial strategy are to build the food chain and never to break it. There was a perceived tendency to use the government as a technological innovator which underwrites major initiatives and then virtually transfers them to corporations which develop the applications. In doing this they preferred to leapfrog current technologies by focusing on the next generation. This approach was felt to characterize both the Europeans and the Japanese fairly well, with RACE, Eureka, and Pan-Europe (1992) being examples.

C. Standards

The role of standards is very important, and it was agreed that transition to new television capabilities must start with today's television -- it will not go away soon. Nonetheless it was suggested that at some point the U.S. should establish a timetable for explicitly phasing out NTSC. Further it was felt that the FCC cannot limit non-broadcast media to the use of FCC broadcast standards, and therefore it is essential that a "friendly family" of standards be developed which permits economic interconnectivity. To have multiple non-compatible standards would be most unfortunate -- the issue is not so much the number of standards, but rather their compatibility.

D. DRAMs

It was recognized that the U.S. is effectively out of the merchant DRAM[2] business, largely because foreign competitors have been willing to continue to produce at plant capacity irrespective of the price their output commands. It was estimated that one significant DRAM plant would cost the U.S. two billion dollars (and satisfy a significant portion of the U.S. demand). Continued U.S. DRAM production was felt to be critical to the competitiveness of U.S. electronics firms whether or not this plant itself would make a profit because of the central role of DRAMs in determining product performance and cost. It was estimated that one-third of all DRAMs are currently used in consumer electronics (including home computers) and that this proportion could double over the next ten years. It was suggested that establishment of such world-class U.S. domestic capability was absolutely essential to preserve the independence and integrity of U.S. electronics manufacturers in an uncertain competitive world.

E. Congressional/Governmental Situation

There was widespread agreement on the need for federal government action this summer or fall, and that emergence of one or more strong national leaders from industry would be extremely important and useful. Present problems of the current administrative transition were felt to be significant in that the delays in launching new initiatives could hinder needed actions in this industrial area. Transitional problems include not only the necessary learning time for new political appointees to the administration, but also delays introduced by new assignments to congressional committees.

Approximately seven congressional committees and subcommittees are involved. One particularly active series of hearings is that being conducted by

Congressman Markey, who has already held several and apparently plans 3-4 more during the coming months. Additional members of Congress known to this group to be currently involved in these issues are Brown, Dingle, Hollings, Levine, Ritter, Roe, and Walgren.

F. Television and Related Future Businesses

Partly because foreign firms use the large U.S. market as a battleground for global market share, traditional television manufacturing for this U.S. market has generally been unprofitable for all participants, and thus has been a generally unattractive business for U.S. corporations. But it was felt that television sets alone are not the issue. What is actually at stake now in television is the future of the high resolution systems industry and of related industrial sectors in computers and telecommunications. The intersection of these "information" sectors will provide the basis for an entirely new and broad industry. One important first step for this U.S. industry, given the present competitive situation, would be formation of industrial consortia, initially with an R&D focus, but most likely extending to manufacturing at global scale.

G. Relationship Between Manufacturing and R&D

Recent studies of industrial competitiveness have emphasized the critical importance of "design for manufacturing" and the need to integrate much better the choice and development of manufacturing processes with the design of products. It is increasingly recognized that most manufacturing firms without such strong cross linkages between product design and manufacturing will have a significant competitive disadvantage in global markets. Thus it was felt that consortia must extend beyond research and development to include considerations of the manufacturing processes, pilot manufacturing, and scale-up issues. It was suggested that bringing a product to scale was significantly different from going only to pilot production. Some argued that it is important to keep one team the whole way through, from R&D to manufacturing at scale, and others felt that manufacturing engineers detailed to a joint R&D project would be eager to bring home the fruits of research.

H. Antitrust Issues

Antitrust is clearly an area of great interest, where the issues include not only the law itself, but also how the law is perceived and the debilitating precautions firms may take to reduce their perceived risks.

There are two concerns with antitrust law: a government suit that could result in an injunction to unscramble the activity, or a private suit that could result in treble damages. Three ways to guard against these are:

1) A legal opinion from an expert stating that the activity is framed in an acceptable fashion. This option offers reassurance but no real protection: such opinions are relied upon perhaps 95 percent of the time.

2) A business review or advisory opinion from the Department of Justice (DOJ). Most requested reviews are obtained in 3-6 months, and they offer protection from government suits, but not from civil suits, where they are nonetheless frequently persuasive.

3) A statute, which is the only means affording total protection, but it is very difficult to obtain and is usually not industry specific.

It was explained that the risks of joint activities were least when the collaborators represent a small fraction of the actual and potential competition in an industry and when they focus on research and the early stages of development. Even in the manufacturing stage, joint ventures which do not create or abuse market power may now be permitted, but the risk of treble-damage civil suits clearly is increased. Such perceived risks have largely precluded many manufacturing joint ventures, even in sectors where U.S. firms currently have little presence. It was generally felt that legislative clarification of this issue would therefore be very useful. Such legislation should specifically reduce or remove risks for firms collaborating in a market area otherwise overshadowed by strong foreign competitors. Some participants suggested less controversial arrangements such as joint ventures should therefore be explored in preference to consortia.

It was noted that there is precedent for finding that antitrust laws are not applicable to a state or federal government entity, and the Supreme Court has on numerous occasions explored the extent to which such immunity could be extended to private entities acting in partnership with government. Therefore the government may now have sanction to immunize a consortium or venture by participating in it[4]. Further, it would appear to be a small extension of this precedent through legislation to give the government sanction to immunize a consortium from antitrust challenge if 1) some government support is provided to the consortium and 2) if the DOJ provides an opinion letter finding that the proposed venture is not anti-competitive. Specific legislation would be required for this extension of precedent, but it would not require the need for broad reexamination of U.S. antitrust law. It was felt that a broad reexamination would incur the risk of major delays.

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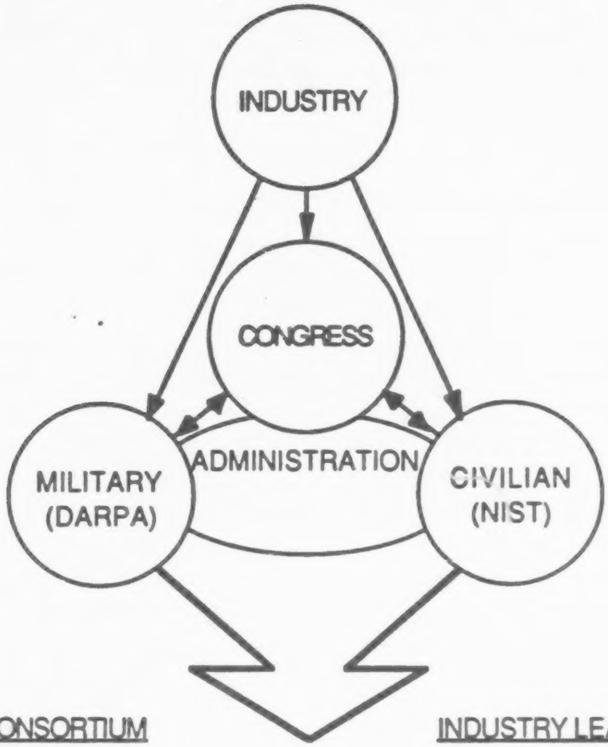
[4] See , for example, Parks, v. Brown [317 U.S. 351, 352], or Southern Motor Carriers rate conference v. U.S. [471 U.S. 48 (1985)].

I. Participation by Foreign Firms

There was consensus that the principal objective of these consortia must be establishment and maintenance of a broad world-class U.S. domestic technological and manufacturing capability by U.S.-owned electronics firms. Participation by foreign firms consistent with such objectives of a consortium might include sharing critical technology, conduct of important research and development in the United States, significant purchases of related U.S. high technology products (strengthening the "food chain"), etc. It was suggested that such participation should be defined not in terms of rules and regulations, but rather in terms of substance responsive to evolving situations. If participation by foreign firms was consistent with these objectives, then the criterion of reciprocity would be invoked. The key element of reciprocity would be that similar organizations in the home country of a foreign firm would be open to U.S. participants on terms that prove to be equal in practice to those of the U.S. consortium.

J. Relative Roles of Industry and Government

The consensus was that consortia should be industry-led and that government should provide an environment within which such industry initiatives could be successful. Such government steps should include 1) providing limited financial support, initially for selected research and development initiatives, but also possibly extending to support necessary to permit full-scale manufacturing, 2) equalizing long-term capital costs for U.S. participants relative to foreign competitors, and 3) providing a more hospitable antitrust environment. Helping to ensure reciprocal access to foreign markets and adherence to fair practices by competitors were also felt to be important. Furthermore, to the degree practical, competition among U.S. firms could be helpful, particularly in early R&D phases. One recommendation was to follow the example of the Bird Foundation, a joint U.S.-Israeli foundation that responds to proposals for jointly funding risky new technologies. DARPA and NIST were felt to be two appropriate vehicles for the government to use in addressing such technology issues. Figure 2 was presented as a schematic rendition of the proposed government/industry partnership.



CONSORTIUM	INDUSTRY LEADER
HDTV (High Definition Television)	AEA (American Electronics Association)
DRAMs (Dynamic Random Access Memories)	SIA (Semiconductor Industry Association)
HRS (High Resolution Systems)	(Not yet identified)

Figure 2. Industry-Led Consortia to Revitalize U.S. Electronics Industries (HDTV and HRS might be unified)

K. Implementation of Workshop Recommendations

Participants agreed that the Workshop had been very helpful in developing understanding and consensus on a number of important issues and that the essence of these discussions should be made available in a report. They also agreed that additional workshops on related critical issues could be very helpful.

III. Issues Addressed in Working Group A: Organizational and Effectiveness Issues

A Foreign Participation

The working group attached particular importance to the conduct by foreign firms of significant research and development activities within the United States, and it noted that Thomson and Philips appeared to be particularly effective in this area. Opposition to a blanket prohibition of foreign participation in U.S. consortia was based on concerns for good business practice and for reciprocity, because U.S. firms operating abroad have the mirror-image problem. For example, just as IBM has made important technical contributions to European and East-Asian computer manufacturing firms, so could non-U.S. firms make similar contributions here. Such contributions have to be evaluated on a case-by-case basis.

Meaningful broad penetration of the Japanese high technology market by U.S. firms should be linked to the issue of consortium reciprocity. Linkage to issues such as dumping, intellectual property, etc. was also advocated. It was noted that although such access is presently very difficult in Japan, its market is not impenetrable.

In response to the question concerning how foreign firms with enormous technological advantages could be excluded from U.S. consortia (or if they should be), it was noted that the net contribution to the reestablishment of a self-sustaining U.S. technological base plus the key issue of reciprocity should be the key criteria for making such a determination. The question should be decided on an ad hoc basis reflecting all relevant circumstances.

B Local Research and Development and Intellectual Property

It was felt that conduct of, and some fair mechanism for sharing, significant research and development in the U.S. should be given considerable weight when discussing the contribution of a foreign firm to reestablishing the U.S. technology base, and that requirements in this area may even be desirable. Participation in a consortium could be partly on the basis of the technology which member firms, and potential member firms, brought to the table.

C. Profitability, Protection, and Industrial Policy

Profitability is difficult to achieve in markets where there is global overcapacity, price cutting, or dumping. Actions which would be considered "anticompetitive" under U.S. laws often occur in global markets or in the tactics of foreign firms competing with U.S. firms. This can lead to plant closures in the U.S. Sometimes lack of technology contributes to such plant closure. The U.S. needs to protect new start-ups in its consumer electronics manufacturing base against such threats.

Although it was argued that such issues require us to address broad issues directly, the discussion in Working Group A focused on industry-led strategies. It was argued that a basic issue--manufacturing capability and the need to encourage large-scale production--was of great importance.

D. Cost of Capital

The key role of the relative cost of capital among nations in influencing long term U.S. capital investment was noted. It was argued that if the cost of capital is 3.5 percent in Japan versus. 11 percent in the United States, then the federal government must adopt policies that reduce the effective U.S. cost of capital in order for the playing field for U.S.-owned firms, at least in critical industries, to be level. One direct consequence of higher costs of capital to U.S. firms is that they must focus on short-term opportunities where the differential cost of capital is less important. What appears as a "lack of vision" by U.S. firms is really a rational economic response to the higher cost of capital that they face.

E. Market Access and Corporate Strategy

It was noted that the Japanese pattern for introducing new technologies is to test them and to build scale in the domestic market, and only then to shift to production for export. It was argued that Japan is tending to integrate with the rest of the Pacific Rim, and that this market is partially closed to the U.S. The European market also shows signs of closing in part, thus potentially leading to three major free-world economic blocs. Concern was expressed that such blocs could seriously influence corporate strategy and even lead to economic warfare among the blocs--or worse.

F. Government Purchases

It was suggested that military and government use of flat high resolution screens and related components over the next ten years could rival the U.S. non-governmental market. Consensus on this issue was not tested, but it is true that federal and state budgets do represent a significant fraction of the U.S. economy.

G. Initial Evolution of the HDTV Market

It was suggested that one avenue of entry to the HDTV market could be via advanced work stations, initially for military, business, and related markets. At the moment flat screen displays are being driven by laptop computers and watches. Advanced work stations could constitute an infant industry that would lead the U.S. back into HDTV. Alternatively, the HDTV market could be entered via the natural evolution toward advanced television, for which improved flat screen displays and advanced semiconductor technology would be key elements.

H. Industry-Government Relations

There was support for a structure that provides for government-private interactions on a broad basis. There was consensus that such a strategy which provides for corporate diversity and initiative and with the government providing a supportive climate was preferable to other alternatives considered.

There was also recognition that the nature of such consortia will necessarily evolve as experience is gained and as broader understanding of the issues develops. Considerable support was expressed for the efforts of the American Electronics Association in this area and for Sematech as an early first step. Support was also expressed for patent pooling as one of the mechanisms for strengthening the economic integrity of such consortia.

The objective of such consortia would be to ensure that U.S. firms have meaningful U.S. productive capacity at all levels in the technological food chain. It was felt that there should be vigorous domestic competition and market expansion, and that governmental and private measures may be required to promote equality of access and protection in international markets. Most important is that the U.S. effort must be industry-led and that more major U.S. corporations must come forward and participate. The interests of both the Department of Defense and the Department of Commerce are involved and both should participate in this area, principally in support of critical research and development where high risks preclude adequate private U.S. investment. DARPA (DOD) and NIST (DOC) were cited as two relevant agencies for this purpose.

I. Links between Technology and Production

Sematech was seen as an important first step in establishing precedence for corporate cooperation in integrated research and development efforts. One problem with Sematech is that if it should design new manufacturing equipment there may be too few U.S. firms to purchase it. The importance of design for manufacturing was noted. The industry-led consortium strategies discussed in this workshop differ from Sematech in that 1) there is much more emphasis on ensuring that any cooperative research and development is competitively linked to manufacturing, and 2) members of the consortia would include firms that are competitors.

J. Trade

All agreed that it is critical that the U.S. government enforce existing trade laws, including effectively protecting against dumping and providing reciprocal access to markets. It was suggested that the definition of dumping should be reexamined and perhaps should be based more on relative prices. It was noted that if the U.S. domestic market were effectively defended against unfair practices and imbalances in capital costs, the market would become much more attractive to American investors, and U.S. firms would be more eager to invest.

IV. Issues Addressed in Working Group B: Standards and Services

A Agenda

The agenda for the working group was:

1) Open Architecture Receivers
2) Standards and Control of Markets (proprietary technologies)
3) Immediate Standards Issues
4) Vision Statement

B Open Architecture Receivers (OAR)

An open architecture receiver has a generic modularized structure that facilitates its ability to handle multiple standards and to be upgraded. For example, it might support multiple transmission or display standards. The ease with which such receivers could handle multiple standards and evolve as technology evolves without requiring immediate replacement is a major advantage, but it requires that multiple standards constitute a "friendly family". Multiport receivers can also handle more than one standard but generally would not be upgradeable as standards or owners' preferences change. Poorly chosen standards make interconversion between standards more difficult and expensive.

The issue of cost and complexity of an OAR was raised immediately as a potentially serious obstacle. The lack of data on the costs and trade-offs for both open and closed designs for HDTV and other high resolution systems was noted. Nevertheless, it was argued that OAR concepts were technically and strategically promising and that user-friendly low-cost OARs may be feasible. For example, an extremely simple (and inexpensive) "naked" OAR could be upgraded by adding small plug-in chips or boards. It was agreed that OAR is not the same as Open Network Architecture (ONA), a regulatory "architecture".

After some discussion it was generally agreed that:

- **The flexibility of an open bus structure, responsible for the success of the Apple II, IBM PC, and Sun workstations, holds promise for the design of flexible dual-use high resolution systems such as HDTV OARs.**

- **Cost analyses of open architecture versus multiport designs should be performed.**
- **An OAR would greatly help the US compete internationally in high-resolution systems markets.**
- **A low-cost user-friendly OAR is critical and probably feasible.**
- **Preparation of a short document "Questions and Answers concerning the potentials of OAR" would be useful in educating concerned parties.**

Some historical perspective was provided by noting that Dumont had advocated an open architecture receiver (with flexible scanning standards) as an alternative to the closed-architecture NTSC standard in the early 1940s. Dumont's proposal was rejected by the Radio Manufacturer's Association on the grounds that Dumont (subsequently a major TV manufacturer) was not a radio manufacturer, and therefore had no standing to participate in standard-setting for television.

As a side note, similar pressures in the standards process were alleged in the current debate concerning potential U.S. and global adoption of the NHK 1125-line production standard. One of the key HDTV standards issues involves use of interlace instead of progressive scan. Cited as being illustrative was a key meeting of the Society of Motion Picture and Television Engineers (SMPTE) on February 17 and 18, 1985 which addressed this issue extensively. Several votes were taken as the meeting progressed. For the first vote 17 participants voted for progressive scan, while only 4 (3 from CBS affiliates and one from Sony) voted for interlace. Nonetheless, at this meeting the minority position was eventually adopted, partly on the allegedly mistaken belief that time pressures forced adoption of the first (and only) standard then available. US manufacturing firms then had no strong technical initiatives or interest in this area, and appeared to have abdicated. At the meeting of March 19, 1985 of the Advanced Television Standards Committee (ATSC), originally formed by the EIA, NAB, SMPTE, and IEEE, a separate vote was taken with the result that 21 favored the NHK standard, 14 were opposed, and 6 abstained. Although this fell short of the two-thirds needed to formally approve the NHK standard, it again emerged with SMPTE endorsement as there were no U.S. firms in a position to develop or promote the preferred progressively scanned alternative. It was suggested, however, that there may be at least one U.S. patent of some use if the NHK production and related MUSE transmission standard are adopted[5].

It was further alleged that foreign interests now dominate the ATSC to a degree that should disqualify it from a central role in US policy making. It was agreed that if inappropriate pressures in the US or in the ITU's CCIR Study Group 11 on HDTV actually existed and could be documented, the results would be of broad interest.

C. Proprietary Technologies and Standards

The first question discussed was whether it made a difference which standard the U.S. uses. It was agreed that the answer was yes, it does make a difference. It was noted that if it did not, the proponents of the 1125-line 60-Hz interlaced production standard would not continue working so hard to have it adopted in the U.S. and endorsed as the single global standard by the CCIR, and the Europeans would not be opposing it so strenuously--they favor 50-Hz progressive scan with a different number of lines. While no government action can guarantee market success, the adoption of 1125 could help preclude U.S. manufacturing firms from succeeding in related high resolution markets because of the Japanese lead on the 1125 learning curve and in related patents. An asymmetry in present national standards setting and trade policies in these areas was noted. Conclusions reached include:

- **Open architecture does not mean non-proprietary. The U.S. could support open architecture designs, and also seek to develop proprietary positions in high resolution systems technologies.**
- **The most protectable element of an OAR was expected to be special chip sets and algorithms, including encoding and decoding techniques.**
- **The U.S. can not always depend on patents and licenses for critical technology from Europe or Japan, whereas foreign firms can usually count on such licenses for U.S. technology at open market prices.**
- **There was no compelling reason for the United States to**

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[5] Rossi, "Method and Apparatus for PCM-Encoding NTSC Television at Sub-Nyquist Rate"; US 4,065,784, December 27, 1977. See also NHK Laboratories Notes 235 (T. Yoshino and A. Ohya) and 304 (Y. Ninomiyo).

continue to inflict economic damage on itself by perpetuating asymmetries in technology trade policy.

Discussion shifted to patent pools and technology licenses for U.S.-owned firms participating in high-resolution systems consortia. The computer industry's practice of maintaining a second source of supply, e.g. for semiconductors, was judged worth emulating by the current initiative. It was suggested that the rights to licensed technology should revert to the industry consortium if a member firm is sold. On the issue of foreign participation it was agreed that a consortium should be open on a reciprocal basis. Opportunities for cross-licensing technology needed by the consortium, and the operation of research and development and manufacturing facilities in the U.S. were agreed to be some of the factors to be taken into consideration in determining which firms should be permitted to participate in a consortium. The working group agreed that:

- **Adoption of efficient manufacturing technology and productive management techniques (such as work teams) to ensure high product quality and reliability were recognized as being just as significant as standards in determining whether U.S. reentry will be successful.**

- **Even if the technology is designed and a proprietary position is held in the U.S., those with better manufacturing capability may design around the standard.**

- **Thus, the U.S. must go beyond a focus on technology, to consider such issues as management and manufacturing techniques, labor relations, trade policies, and the cost of capital.**

D. "Friendly Family" of Standards

High resolution systems for program production and program interchange will be completely different from present systems and will require different technical standards. The difficulty of transcoding interlaced 1125 (of repacking data from one video format to another) was noted. Such repacking, however, is needed for program interchange and production of HDTV. 1125 interlaced therefore poorly satisfies the requirements for the functions it is proposed to fulfill. It was noted that the original study question of HDTV in the CCIR concerned satellite broadcasting, for which 1125 interlaced (and MUSE) is better suited than it is for production, terrestrial broadcasting, or cable transmission.

Adoption of a "friendly family" of high resolution and HDTV standards was considered important for the production of low-cost open-architecture receivers.

It was suggested that, from a technical point of view, the proper sequence of standard setting is first to choose the receiver and then to set standards for transmission and production--the reverse order from that followed in the current CCIR work on HDTV standards.

E. Immediate Standards and Technology Issues

Asymmetries in U.S. practices relative to Europe and Japan were again noted. It was argued that the Japanese and Europeans have always better understood and exploited the international economic impact of standards, while the U.S. has traditionally emphasized the assessment of international standards on technical grounds.

It was suggested that there may be a Japanese strategy of "giving away" the rights to the 1125 production standard, while later not so freely licensing the closely related MUSE transmission standard and technology in which Sony, NHK, and perhaps CBS were thought to have proprietary interests--such a strategy might lead to control of the receiver market. It was stated that a U.S. high resolution systems consortium should adopt a similar strategy, but based on a different standard. With regard to a U.S. consortium it was agreed that:

- **Decisions will be made in the next few months on critical standards issues affecting the interests of such a consortium.**
- **Other nations and their firms are coordinated in this area, but U.S. manufacturers are not.**
- **Such a U.S. consortium must have the capability to respond and participate significantly in standards forums.**

Some of the principal standards forums and parties currently active in HDTV standards setting include:

CCIR	International production, program interchange, broadcasting, and satellite broadcasting standards
FCC	U.S. broadcasting standards
ATSC	U.S. broadcasting, production, program interchange standards for advanced television systems
SMPTE	U.S./international production standards
Cable Labs	U.S. cable transmission standards
Industry	Production, program interchange, broadcasting, satellite broadcasting standards (e.g. Zenith, NBC, RCA, Thomson, Sarnoff, Del Ray, Philips, Sony, CBS, AT&T, IBM, Bellcore, etc.)
DARPA	Technology support for high resolution systems
Eureka 95	European production, program interchange, broadcasting, satellite broadcasting
NHK	Japanese production, program interchange, broadcasting, satellite broadcasting
University	High resolution systems standards (MIT, NYIT)

Those potentially more active in high resolution systems standards setting include additional private firms and universities, plus:

CMTT	CCIR/CCITT international television broadcasting and terrestrial transmission joint working group
ISO/IEC	Private international voluntary electrical and electronics high resolution systems standards
DOC	NIST/NTIA
U.S. Consortia	High resolution systems and transmission standards
T1	High resolution transmission standards

F. Vision Statement

In contrast to the other subjects the working group addressed, consensus on a vision statement was not reached. It was agreed, however, that:

- **One goal is to facilitate the emergence of "American entities manufacturing television systems with American parts, labor, and knowledge."**

- **It would be sensible for a TCA to emphasize products people will want, such as flat screen TV's.**

- **To develop a clearer vision of advanced television and to understand the demand for advanced television systems and services, thorough and sophisticated research on video communications systems will be required.**

- **Programmers, network operators, and cable television firms should be involved, so that realistic prototype services could be tested.**

- **Research on high resolution systems and broadband networks should also be conducted in testbed demonstration projects and subsequently in larger pilot projects.**

- **Consortia should develop displays, semiconductors, and possibly entire systems.**

- **Demonstration and pilot projects should be open to foreign participation on a reciprocal basis.**

- **As federal law prohibits more than 25 percent foreign ownership of U.S. broadcast facilities, for national security reasons, foreign participation in U.S. high resolution systems broadcast demonstration and pilot projects would therefore presumably be restricted to no more than 25 percent.**

V. Issues Addressed in Working Group C: Technology and Manufacturing Capabilities

A Technology Status

After discussion of the objectives of the working group, the group began by listing technologies relevant to the manufacture of high-resolution video displays. These technologies were divided into two categories, those for which the U.S. was believed to have a meaningful manufacturing base and those for which it does not. These two lists are presented in Figure 3. The relative sums of money needed to establish a meaningful U.S. capability in each of the relevant technologies was estimated, and those technologies deemed to require the largest investments were DRAMs, displays, manufacturing science and technology (including robots), and optics. In some cases it was felt that the technology was obsolescent and that such investment might be misplaced, e.g., deflection yokes for CRTs. It was felt that a central effort would be required even to maintain those technologies we do have against the competitive pressures posed by the concerted efforts of certain overseas competitors. That is, it was generally felt that almost no technology was safe.

Figure 4 presents a list of merchant vendors of integrated circuits with a separate listing for applications specific integrated circuits (ASIC). Another list characterizes the leaders in IC interconnects and the situation in IC packaging materials. Additional areas where the U.S. is losing its markets are also presented. It is clear from these lists[6] that the U.S. is not the leader in any of these areas, and in emerging technology areas the situation is even more precarious. The linkages between materials, IC packaging, and multichip modules represent a particular vulnerability for U.S. semiconductor manufacturers. It was noted that firms are extremely reluctant to reveal or discuss their weaknesses in public.

Figure 3. High Resolution Systems - U.S. Technology Capabilities

Technologies[7] We Do Not Have	**Technologies We Do Have**
Displays	Systems Integration
Yokes	Software
DRAMs	Digital Logic
Digital GaAs	CPUs
Low-End Print Engines	ASIC
Materials	Microprocessors
Packaging (Semicond.)	CAD/CAE/CASE
Test Equipment	Large Family Rooms
Photo Lithography	
Manufacturing S&T	
Optics	
CCDs/Imaging Devices	
Mechanisms	
OEIC (Opt.-Electron. ICs)	

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[6] Provided by H. K. Bowen.

[7] Technologies for which we have competitive state-of-the-art low-cost manufacturing capabilities at scale.

Figure 4. Leading Vendors (in order of market share)

Total IC's	ASIC	IC Inteconnects, High performance multichip modules	U.S. Losing Markets, Examples
NEC	Fujitsu	IBM	Si crystals, wafers
Toshiba	Toshiba	NEC	IC's
Hitachi	NEC	Fujitsu	Capacitors
Texas Inst.	AMD	Hitachi	Varistors
Intel	LSI Logic	Kyocera	Cutting Tools, etc.
Motorola	TI		
Fujitsu	Motorola		IC Packaging Materials:
National Sem.			Japan supplied 40% in
Mitsubishi			1978 and 80% in 1988
Philips			

B. Technology Linkages

The importance of the linkages between different technologies was stressed. Public understanding of these linkages would increase support for U.S. initiatives in this area, and would provide a better sense of how the industry should focus its efforts, expand its breadth, and establish the desired scale of manufacturing capability.

C. Manufacturing Equipment

A significant opportunity for productivity enhancement was suggested. U.S. firms purchasing sophisticated manufacturing equipment often keep improvements they make to that equipment proprietary so that competing U.S. firms must either re-invent these improvements or do without. Although Sematech might be able to improve this situation for some types of manufacturing equipment, the problems and opportunities were felt to be much broader.

D. The DARPA Initiative

It was understood that DARPA, an advanced research and development arm of the Department of Defense, has an initial 30 million dollars allocated to support of high resolution displays and image processors but that it will not initially address either cameras or video recording. It is hoped that this budget will be increased and that venture capital will be available to supplement promising proposals. An area of emphasis for image processors will be semiconductors and other means for handling video signals within a nominal bandwidth such as 6 MHz. The objective is to help enhance the integrity of the U.S. manufacturing base relevant to these dual-use technologies. Proposals were due February 27, 1989, and the level of activity has been high. The working group commended DARPA for its effort and agreed that it had selected two of the most important areas to fund. The importance of DRAMs and displays were both noted as being critical ingredients in future HDTV systems.

E. Business Issues

It was felt that part of the business problem is the limited incentive to capitalize, particularly in long term investments. The enormous impact of pension funds and insurance companies on the investment climate was noted; it is essential to make it attractive for them to invest in these technology areas. The importance of lowering the relevant U.S. cost of capital was noted and that lowering capital gains taxes on technology investments might be very helpful; it was argued that in providing such tax preferences, such as lower capital gains taxes, the government should single out manufacturing investments rather than including less production-oriented forms of investment such as general real estate. In particular it was felt that the government should be a catalyst in getting high resolution system technology (including HDTV) started in the U.S. The importance of progress in displays was noted, and this was an area in which the U.S. might be able to excel.

F. Consortia

The purpose, forms, and functioning of consortia as a means for advancing technology were discussed.

Examples of consortia considered included one working on high resolution systems, and perhaps another concentrating on manufacturing and machine tools, including milling, casting, welding, lithography, etc. One suggestion was that a high resolution system consortium might embrace components for work stations, memories, television, HDTV, radio, and other low cost or related consumer electronics products. Alternatively one consortium might focus specifically on DRAMs, another on displays, etc. The relative advantages of these approaches was not resolved. The possibility of establishing a more end-product oriented consortium was also noted. Such a consortium, for example, might develop a combination TV/PC.

It was noted that Japan utilizes MITI to do long term projections, even 50 years in advance, whereas we seldom look even 10 years into the future. There was some concern expressed that Sematech may be too heavily focused on yesterday's problems and not sufficiently strongly oriented to the future. Such long term projections could be one of the functions of a consortium. A contrary view was that one becomes a leader by innovating rather than by doing 50-year plans. It was felt that short term planning and milestones were nonetheless an important function of a consortium or its members.

The sources of competitive advantages of a consortium relative to isolated firms were felt to include cooperative R&D, government relations, information and patent exchanges, and greater success for governmental relations in such matters as loan support, discussions and rulings concerning accounting and tax credits, trade regulations and enforcement, assured markets through government purchases, and improved communications concerning trade violations, tariffs, impact of subsidies, and other forms of government regulation. Other areas of cooperation between firms might include studies of legal, political, market, standards, competitor evaluation, and personnel issues, and other areas. Information sharing with universities, government institutions, and other firms would be facilitated, and might extend to better awareness as to available intellectual, manufacturing, technology, and other resources.

It was felt that the potential impact of such consortia would be difficult to establish in advance, but that it could be significantly positive, and their establishment should therefore be pursued creatively and aggressively.

APPENDIX

ENTITY POSITION STATEMENT

A NATIONAL INITIATIVE FOR THE ELECTRONICS INDUSTRIES

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(202) 785-0017

- ***The U.S. must immediately re-establish significant technological capability and domestic manufacturing of world-class products by U.S.-owned firms based on electronic and related technologies that serve both civilian and military purposes.***

- ***The situation is critical. A proactive stance by the Federal Government is required if these goals are to be achieved.***

- ***A cooperative organization structured to function in the private sector, but with Government support, is an appropriate initial vehicle for implementing these goals in this country.***

- ***The organization and its Government support must be in place this year.***

- ***In the longer term U.S.-owned domestic manufacturers must be able to perform profitably in global markets over a broad technology base under conditions of true economic competition.***

- ***This IEEE Council can assist in catalyzing the achievement of these goals by convening working sessions in the immediate future and providing appropriate support throughout the process of implementation.***

TECHNOLOGY ACTIVITIES COUNCIL	JANUARY 25, 1989
Approving Entity	**Date**

Today progress in electronic process technologies, cost efficiencies, and product quality are determined more by the demands from large scale consumer markets such as those for television, computers, and automotive electronics, than they are from military and space requirements. Linkages and spill-over effects are now becoming more prominent from the consumer sectors into the military, than they are in the reverse direction. The ability to design and manufacture sophisticated electronic and electromechanical systems is increasingly vital to a broad range of military and civilian products important to U.S. national security and to the future U.S. standard of living. Often technologies and components that are essential for civilian applications are identical to those vital for military weapons systems. Such "dual-use" items are also key elements in the evolving U.S. communications infrastructure upon which our economy and democracy depend.

The global consumer electronics market is now principally supplied from the Pacific Rim and to a lesser extent from Europe. The almost total elimination of U.S.-owned firms from domestic production of many dual-use products--and thus the loss of their design and manufacturing capability--represents a great danger to this country's military and economic security in areas such as computers, telecommunications, automation and modern weaponry. The necessity to purchase these products from foreign suppliers is contributing increasingly to the U.S. balance of payments deficit. As a nation we can no longer ignore these linkage and spill-over effects from consumer electronics to military and other national security areas.

Other countries have faced and overcome similar problems: there are lessons taught by their successes and failures that we must understand and incorporate into the process as the U.S. undertakes to reverse the current trends. The first lesson is that without the active cooperation and support of the domestic government, it is virtually impossible for a nation's industry to develop and maintain domestic capability in the face of well established, entrenched and aggressive competitors. U.S. Federal Government support, therefore, is essential as U.S.-owned firms become re-established and evolve to the level of global competitiveness.

An additional early conclusion from prior experience is that, given the U.S. economic system, a cooperative organization structured to function in the private sector is likely to prove to be the best vehicle for implementing initial development efforts. The actions of interested Federal Government agencies in support of such an initiative must be orchestrated and coordinated, and must include regulatory and trade actions, loan guarantees to help move capital costs toward competitive levels, and anti-trust clarifications to permit pilot manufacturing to prove design concepts. In addition, they must include cooperative projects among industrial research laboratories, universities, and U.S. Government laboratories. Progress toward the goals of the initiative must be continually evaluated and adjusted when and as necessary.

Consumer electronics, which include many of the most important and threatened dual-use technologies, are at a crossroad with further implications for the balance of trade. New sophisticated products--extended definition television (EDTV) and high definition television (HDTV)--at both the producers' and the consumers' levels are immediately on the horizon. Other nations are well ahead of the U.S. and are moving aggressively in their planning and development for these products. The Japanese are expected to make their first satellite test broadcasts with these products this year. The Europeans are also very active. Planning by U.S. industry is at an early stage.

Only if the U.S. establishes an independent presence now, will there be hope for the long-term recovery of this industry at a reasonable cost. Indicative of the depth of the problems this country faces in achieving this goal is the fact that the sole survivng U.S. television manufacturing firm is reported to be under serious pressure to sell this sector of its business. There is no likely U.S. buyer. The absence of strong U.S. voices with a major interest in the decisions even now being taken by the Federal Communications Commission and State Department--decisions that will determine the future of the U.S. market for decades to come--is likely to mean that foreign voices will determine their outcome.

The key goal of these initiatives for U.S.-owned domestic manufacturers is that they must be able to perform profitably with world-class products in global markets over a broad technology base under conditions of true economic competition. The implications of each step in the process of re-establishing and maintaining U.S. capability must be assessed against this longer term objective.

The IEEE is a professional society whose purpose is to promote and disseminate knowledge about the electrical and electronics fields, both in technology and technology policy areas. In the immediate future the IEEE-USA Technology Activities Council will sponsor workshops to bring its broad expertise and that of others to bear on these issues to help the nation generate an effective and timely action plan.

Technology Activities Council
January 25, 1989

Origins of RCA

DURING THE VERSAILLES Peace Conference of 1919, it became apparent to Wilson and his advisors that three main areas of international infrastructure (to use the modern term) would be critical in postwar trade: energy; the merchant marine; and the very new technology of radio-communications. All three were linked in some way, most particularly the latter two. Radio (and undersea telegraphy) was dominated by the British at that time.

Assistant Secretary of the Navy Franklin Roosevelt came up with a plan for the U.S. Navy Bureau of Steam Engineering to guarantee Navy contracts to a new corporation which would endeavor to maintain an American presence in radio. This firm was organized by the General Electric Co. and bought out British holdings in the Marconi Wireless Telegraph Co. of America to form a *Radio* Corporation of America. RCA soon became a consortium to pool patents among the key U.S. players. All of this came about because:

1) Radio at the time used steam-driven, high-frequency electric alternators. GE was the major U.S. manufacturer of such equipment. Of immediate concern to the Navy Department was an offer made by British Marconi to GE to purchase exclusive rights for worldwide manufacture and distribution (including in the U.S.) of the Alexanderson alternator, which had been critical in trans-Atlantic radiotelegraphy during the War. Control of these patents by a foreign power, albeit an ally, was viewed as a risk to national security by defense interests.

2) The only generally-accepted, commercial application of electromagnetic waves in 1919 was for radio-*telegraphy* in order to enhance maritime safety. The 1912 Titanic disaster had underlined this in the public mind. An international convention to regulate maritime radio traffic had been held in 1911 (a forerunner of the CCIR), with the Navy as our representative. There was little public knowledge at the time of the secret wartime experiments performed by AT&T using vacuum tubes for trans-Atlantic radio-*telephony*; indeed, conventional wisdom was that such techniques could not be perfected.

3) FDR had a close relationship with GE's management, especially its legal department.

The RCA firm started off as a wireless telegraph common carrier and patent holding company. Alexanderson was Chief Engineer while still an employee of GE. David Sarnoff, the U.S. manager of Marconi Telegraph, became RCA's General Manager.

Soon after RCA's formation, it became clear that radio technology had more in its future than just maritime communications. The problem was that three other firms held radio patents necessary for its expansion: Westinghouse (which GE was in the process of purchasing through an LBO at the time); AT&T; and United Fruit. The latter had developed radio technology to improve command and control of its vast merchant marine and plantation operations in Central America. Each participant brought something essential to the table and shares of RCA were more or less distributed among these five according to the value of their technology; the U.S. Navy held in the beginning about 20% of RCA's stock.

But things changed: within two years of the formation of RCA, commercial radio broadcasting became practical (and profitable), something not quite in RCA's original plans. The first two broadcasting stations were AT&T's WEAF in New York City, and Westinghouse's KDKA in Pittsburgh. Quite rapidly, AT&T built three separate networks of stations based on their Long Lines transmission system—the "Red" and "Blue" networks east of the Rockies, and the "Brown" network in the Pacific states. Other attempts to do the same were thwarted by lack of access to quality intercity telecommunications lines. RCA, however, began a domestic radio-telegraph service which competed with Western Union and Postal Telegraph, and threatened to compete with AT&T's private telegraph lines. (AT&T went out of its way to assure stockholders that wireless communications was really not a threat to "wireline" circuits.) AT&T's Western Electric began to manufacture radio receivers in competition with GE. And *television* research had begun in earnest (and in secrecy) at GE, Westinghouse, and Western Electric.

By 1926, RCA had been transformed by its internal contradictions from a holding company (with a telegraph department) into a manufacturing subsidiary of GE/Westinghouse. The Navy and United Fruit had bowed out. But AT&T's relationship was more complicated:

During 1925-6, AT&T and GE/RCA held a secret arbitration to settle a set of complex patent disputes. This resulted in AT&T selling its RCA stock, and an agreement that RCA would manufacture only home *receivers*, while AT&T's Western Electric would make only station *transmission* equipment. The Justice Department pressed GE to spin off RCA as a separate corporation. RCA, now under the direction of Sarnoff, purchased the Victor Phonograph Corporation to gain access to a consumer distribution system. For a nominal one dollar, AT&T sold its radio networks to the new National Broadcasting Company — a wholly-owned subsidiary of RCA. NBC agreed to use WE transmission equipment and *only* AT&T Long Lines for its network connections. GE and RCA agreed not to enter the wireline telephone business, and Congress blessed this agreement by writing its principal terms into the 1927 Radio Act (and hence the 1934 FCC Act).

Television research was transferred in 1929 from Westinghouse to a new RCA laboratory under Zworikin. AT&T formed Bell Labs combining WE's labs and the Long Lines radio research department. AT&T and RCA then competed for the sound movie business, but that is another story.

While the original RCA did not work quite as its sponsors had expected, the principal goal of this government/industry consortium -- strengthening the incipient U.S. electronics industry — had been met. For the next half-century the U.S. dominated world industrial, military, and consumer electronics technology. And, during the Second World War, by an order of magnitude, AT&T and RCA were the largest two military contractors on the Allied side.

■ **Richard J. Solomon, MIT, February 1989**

High Definition Television (HDTV): Economic Analysis of Impact

November 1988

A working document, prepared by

ATV Task Force Economic Impact Team
American Electronics Association

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TABLE OF CONTENTS

Page

SECTION I

FOREWORD i-iv

EXECUTIVE SUMMARY

Objective, Sources, and Approach 1-1
Conclusion 1-2

SECTION II
TELEVISION PRODUCT MARKET SALES PROJECTIONS

ATV Products' Near-Term Impact 2-1

HDTV Receiver 2-1
Table 1, Worldwide Sales Forecast (units) 2-3
Table 2, Worldwide Sales Forecast (USDollars) 2-4

HDTV VCR 2-5
Table 3, Worldwide Sales Forecast (units) 2-5
Table 4, Worldwide Sales Forecast (USD) 2-6

Color TV (all) 2-7
Table 5, U.S. Market Forecast (units/USD) 2-8
Table 6, Semiconductor Value in Color TVs 2-9

VCR (all) 2-11
Table 7, U.S. Market Forecast (units/USD) 2-11

HDTV Receiver & VCR 2-12
Table 8, U.S. HDTV Receiver and VCR Combined Sales Forecast (USD) 2-12

SECTION III
RELATED INDUSTRY MARKET SALES PROJECTIONS

Automated Manufacturing Equipment 3-3
Table 9, U.S. World Marketshare if U.S. HDTV Manufacturers capture 10-50% of U.S. HDTV Market 3-4

Personal Computer 3-5
Table 10, U.S. World Marketshare if U.S. HDTV Manufacturers capture 10-50% of U.S. HDTV Market 3-7

Semiconductor 3-8
Table 11, U.S. World Marketshare if U.S. HDTV Manufacturers capture 10-50% of U.S. HDTV Market 3-12

SECTION IV
COST TO BECOME A MAJOR HDTV MANUFACTURER

Product Cost Breakdown 4-1
Table 12, CTV Production Cost Breakdown 4-1

Engineering 4-2
Production Equipment Costs 4-2
Semiconductor Costs 4-3
Receiver Costs 4-3
Transmission Equipment Costs 4-3

The Technology Driver 4-3

Marketing Concept 4-5

Manufacturing 4-5
Costs to Build a Display Plant 4-6
Costs to Build an Assembly Plant 4-6
Costs to Build a Manufacturing Plant 4-6

FOREWORD

Economic competitiveness has become THE national security issue. A second rate economic power will be hard-pressed to be a leader in keeping tomorrow's World Peace.

The world is poised on the threshold of a revolution in electronics. In combination with a variety of technical breakthroughs, new technologies will become available which are likely to affect the very infrastructure of the U.S. economy.

Advanced Television (ATV), which includes High Definition Television (HDTV), represents one such critical breakthrough. A few view ATV's incredibly detailed images--akin to 35mm film--as simply a boon to "couch potatoes." Most, however, recognize its long-term and far-reaching competitive implications--i.e., the "ripple effect" on other electronics industry segments, especially semiconductors. New HDTVs, for example, will contain large numbers of DRAMS and have processor capability.

ATV is a fundamental new imaging technology with enormous capability to affect not only most electronics industry segments but the balance in end-use markets between cable, broadcasters, etc.

There are chilling implications for non-participation. The U.S. needs to gain a proprietary position in key ATV markets to ensure that technological know-how remains in this country. The end reward for those who design, manufacture, and sell ATV markets is dominance of computers and telecommunications. Those with access to the means by which ATV-HDTV pictures and voice data are ultimately transmitted to the home--e.g., via fiber optics, direct broadcast satellite, terrestrial broadcast, VCRs, etc.--will play a key role in tomorrow's information society where the "smart home" holds center stage.

Loss of consumer electronics has affected today's U.S. competitiveness. It now accounts for about $7 billion or one-third of our electronics trade deficit with Japan. Typically, each $1 billion in trade deficit translates into 12,000 lost jobs.

Total negative impact from the loss of consumer electronics is hard to assess. The U. S. electronics infrastructure is like a biological food chain with many interdependent segments--when one link is weakened or destroyed, other links feel injury. Many believe competitive problems experienced today by the U.S. semiconductor industry can be traced to this lost segment.

Our foreign trading partners from Europe and Pacific Rim countries have established consumer electronics plants in the United States. They have brought much benefit in providing jobs for U.S. citizens. Harper's Index recently estimated that

Japanese companies located in the United States have created some 230,000 jobs for U.S. workers. They also estimate that the U.S. has returned the favor--creating some 236,000 jobs for Japanese citizens.

Europe's Thomson and Philips, in particular, have extensive U.S.-based R&D and manufacturing. Proprietary information suggests that European consumer electronics companies based in the United States use approximately 39 percent U.S. materials compared to 10 percent used by Pacific Rim countries manufacturing here. This information is a year old and improvement in these percentages is believed to be occurring.

Yet, consumer electronics "manufacturing" in the U. S. overall consists of assembling foreign-made components into products. The AEA Economic Impact Team found that 28 percent of automated manufacturing equipment used for production of present TV sets is bought from U.S. companies, compared to 72 percent from foreign.

Reliance solely on foreign-owned U.S. based companies to produce products using ATV-HDTV technology is insufficient primarily for three reasons. One, without U.S. patent rights, profits will flow out of the United States; these dollars will progressively drive innovation that soon outpaces U.S. technological know-how, "ripples" out into related industry segments, and erodes world U.S. marketshare. Two, while foreign owned U.S. based manufacturers will create NUMBERS of new jobs, many others will be lost. And, third, the new jobs created are unlikely to be of the same KIND and value as those lost.

A generally accepted formula is that each engineer creates 8 secondary and 24 tertiary jobs. No matter how many TV tubes are produced in the United States, assembling glass and wire into wooden boxes requires significantly different skills and talent--and commands lower wages--than the engineering and technical skills required to design and manufacture complex integrated circuits. Large numbers of today's consumer electronics technical "driver jobs' are surely somewhere off our shores. The idea at heart of AEA's ATV Task Force is to explore how to bring those "driver" jobs back.

The rest of the world--our competitors--is thinking big about the issue. The Japanese government and its industry have spent 20 years and some $700 million in perfecting the technology. Europe spends $200 to $250 a year on its Eureka Project. European representatives announced at a recent National Association of Broadcasters event that they set the HDTV market at some $5 trillion. While U.S. estimates are more conservative, there is worldwide agreement that a very sizable opportunity exists.

The difficulty comes when one tries to assess the impact if the U.S. is not a player in ATV. What, for example, will be the impact on other industries such as optics, glass, graphics, print, film, tape, automated manufacturing equipment, personal computers, semiconductors? What products are in the laboratory stages of development or research which could be realized by the actualization of ATV? What and when are other non-consumer, business-industrial product-lines likely to spin out of ATV? How will ATV impact the defense industry and related products in weapons systems?

How can one estimate the cost of re-entry? What processes are necessary to develop ATV technology? Do they require situations and developments not yet implemented or in widespread use?

Might there be a spill-over affect in cost reduction to other industries as well as a revenue-producing aspect? For example, certain forms of ATV will allow the television set to be utilized as a central processing unit in the home, not just a one-way vehicle for receiving entertainment media. As it becomes an interactive medium itself, functions performed currently by other products or not at all may become possible, generating enormous potential for service industries through transactions.

The AEA ATV Economic Impact Team wrestled with these questions for three months, grappling with impact projections of HDTV on three market segments--automated manufacturing equipment, personal computers, and semiconductors. Obviously, different assumptions will generate different results. The shortcomings of such projections are inherent. Among shortcomings in this report:

- Many other product lines may be heavily impacted in the future and may not be identified by a product-line focus;
- Processes and services which are likely to be affected are ignored, as well as millions or billions of dollars these may generate or save through cost-reductions;
- Future applications and spin-off industries are not factored into the equation.

Since it is impossible to know when HDTV's "ripple" effect will occur (i.e., what new product spin-offs may erode market share in non-consumer electronics fields), quantifying market impact requires extensive time and resources beyond those of the AEA ATV Task Force. This "working document," therefore, will be modified as other studies bring information to bear on it. AEA's Board of Directors has called for third party studies on the subject--one by the National Research Council and one by the National Academy of Engineering. In the meantime, the information is offered to indicate trends of impact or the best judgment of experts.

AEA ADVANCED TELEVISION TASK FORCE
PARTICIPATING COMPANIES

ADVANCED MICRO DEVICES
ANADIGICS
APPLE COMPUTER
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AT&T
BIS MacKINTOSH
B.R.I.E.
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KENNETH OSHMAN, CONSULTANT
PROMETRIX CORPORATION
RAYCHEM CORPORATION
SUN MICROSYSTEMS
TEKTRONIX
TEXAS INSTRUMENTS
WESTERN DIGITAL IMAGING
VARIAN
VPL RESEARCH
ZENITH

SECTION I

EXECUTIVE SUMMARY

OBJECTIVE

(1) To identify trends in potential worldwide and U.S. markets for high definition television (HDTV) and related products through the year 2010, (2) to give a perspective on the impact of HDTV on the U.S. marketshare if the U.S. holds a weak, strong, or medium position in the U.S. HDTV market in three key electronics industry segments -- automated manufacturing equipment, personal computers, and semiconductors; and (3) some idea of the cost for a new U.S. entrant to build the manufacturing infrastructure necessary to produce HDTV products.

SOURCES OF INFORMATION

Between July and October 1988, the ATV Task Force's Economic Impact Team contacted Task Force Members, leading U.S. research companies, the U.S. Department of Commerce, the Office of the U.S. Trade Representative, Berkeley Roundtable on International Economics, top executives from former U.S. television manufacturing firms, firms and people previously acknowledged, and many others who had relevant information or opinion of value to this study.

The information in this report, therefore, comes from a variety of internationally recognized research firms and associations. Significant among these sources: Dataquest; Semiconductor Industry Association (SIA); Larry Darby, Consultant, U.S. Department of Commerce, BIS Mackintosh (a NYNEX company).

A "WORKING DOCUMENT" APPROACH

Time and resource limitations make it impossible for AEA's ATV Task Force to forecast with accuracy when and to what degree HDTV's "ripple" effect will occur [i.e., what new product spin-offs may erode market share in non-consumer electronics fields.] The perspective offered, therefore, represents a consensus opinion of industry leaders and merits further study by others.

In spite of these limitations and for purposes of adding to the national discussion, Tables 9. 10 and 11 offer a view of the direct and indirect impact of U.S. companies participating or not in the HDTV market as well as the indirect impact. The indirect impact is especially difficult to pinpoint. For example, if HDTV technology makes U.S. semiconductor manufacturer designs obsolete, the U.S. will lose its innovative edge in many markets--not just the direct $3 billion one in HDTV semiconductors.

CONCLUSION

If the U.S. does not choose to re-enter consumer electronics via HDTV, the country as a whole is likely to experience a continued declining world marketshare in automated manufacturing equipment, personal computers, and semiconductors. In addition, telecommunications and other strategically critical industries could follow.

Loss of these markets will contribute to the loss of both high and low end American jobs in non-consumer electronics fields, significantly increase the U.S. trade deficit, increase the national debt, and lead to the erosion and eventual loss of a U.S. manufacturing base. As is already happening to the semiconductor industry, the U.S. will cease to be the primary innovator in significant End Use Electronics markets.* Implicit in this decline over time is the United States loss of position as a major world power.

For the United States to re-enter the consumer electronics market via HDTV -- a new technology with a huge market opportunity -- it will need the following:

1. A legislative agenda that supports/encourages re-entry into consumer electronics by U.S. corporations.
2. Investment of capital that measures success as growth of marketshare.
3. Development of a new or licensing of a proven receiver technology that is equal or superior to that of foreign manufacturers.
4. Establishment of a U.S. manufacturing capability for production of TV displays and for assembly of receiver components.
5. Implementation of a creative marketing strategy that convinces consumers to buy Enhanced or High Definition (EDTV)/HDTV and the value of buying an American product, along with a pricing strategy that recognizes the Japanese "staying power" when it comes to buying marketshare.
6. Adoption of a distribution strategy based on capturing shelf space currently dominated by foreign manufacturers and underpinned by competitive pricing, better product performance and features, and reliable quality service.
7. U.S. enforcement of anti-dumping laws.

* "End Use market" is a market for stand-alone products which have a significant value to the individual consumer.

SECTION II

TELEVISION PRODUCT MARKET SALES PROJECTIONS

ATV-NEAR-TERM IMPACT

In the near term, foreign companies will leverage their distribution channels to sell Enhanced Definition Television ("EDTV"). These will be replaced in the long term with high definition television sets (HDTV). EDTV offers some improvements over NTSC resolution. It does not, however, compare to the high quality of both display and sound offered by HDTV.

EDTV receivers using the range of four to eight megabits of memory. EDTV digital decoding VLSI are expected to be on the U.S. market achieving respectable sales by 1993. By 1991, sales of a variety of HDTV production equipment will already be substantial.

The near-term U.S. targets for HDTV are video conferencing, video equipment, studio equipment, cable TV equipment, closed circuit TV, medical diagnostic equipment and commercial aviation equipment. These markets may serve as foundations for movement into major consumer End Use markets.

HDTV RECEIVER: TABLES 1 AND 2

HDTV receiver sales to consumers are expected to start in 1990 in Japan and later in other regions. The HDTV Receiver Worldwide Sales Forecast provided in Tables 1 and 2 is based on what is believed to be realistic penetration assumptions:

Penetration Assumptions

(1) Figures are for HDTV, not IDTV or EDTV.

(2) 1125/60 NHK standard is scheduled for satellite broadcast in Japan in 1990. Note: Recognized is that 1125/60 may not be the transmission standard adopted by other major continents.

(3) True HDTV broadcasts, as an evolution from preceding EDTV broadcasts, are assumed to start in the U.S. in 1996. (EDTV broadcasts are assumed to start earlier, in 1993.)

(4) A full service of HDTV broadcasts is assumed to start in Europe in 1997. Wide screen 625 line MAC DBS broadcasts are assumed to begin in 1992.

(5) Reasonably optimistic household penetration rates are based on previous history of color TV and VCR once these markets established themselves.

(6) Comparatively small sales of the 1125/60 NHK system (mainly to non-consumer-users) in the U.S. and Europe are assumed prior to the consumer demand which emerges once locally transmitted HDTV broadcast services begin.

(7) Availability of a range of 1125/60 program material via cable, direct broadcast satellite, pre-recorded videocassette or videodisc is assumed not to be of sufficient quantity or attractiveness to stimulate significant consumer demand prior to full service programming that comes via a locally established broadcast standard.

(8) Projections for the U.S. in Tables 1 and 2 are very close to the historical "take-up rate" for color TV once total sales cross the one million units per year mark. This bench mark is widely accepted as establishing a product as successful in the consumer market.

(9) Forecasts in Tables 1 and 2 reflect the view that prior to HDTV sales (A) EDTV sales are likely to have taken some marketshare in both Japan and the U.S. and that (B) wide screen MAC 625 line TV are likely to have taken some marketshare in Europe.

TABLE 1
HDTV RECEIVER
WORLDWIDE SALES FORECAST

(IN THOUSANDS OF UNITS)

DATE	U.S.	WESTERN EUROPE	JAPAN	R.O.W.	TOTAL	CUMULATIVE TOTAL
1990	1	1	20	1	23	23
1991	5	2	80	3	90	113
1992	7	2	150	3	162	275
1993	10	3	260	5	278	553
1994	20	5	350	6	381	934
1995	30	5	450	10	495	1,429
1996	80	10	620	15	725	2,154
1997	100	50	800	20	970	3,124
1998	250	150	1,000	30	1,430	4,554
1999	500	300	1,200	100	2,100	6,654
2000	1,000	1,000	1,600	700	4,300	10,954
2001	1,600	1,500	2,000	1,200	6,300	17,254
2002	2,600	2,400	3,000	1,900	9,900	27,154
2003	4,900	3,000	3,500	2,500	13,900	41,054
2004	6,500	4,500	4,500	3,400	18,900	59,954
2005	6,700	5,000	5,000	4,000	20,700	80,654
2006	6,800	5,500	5,000	4,700	22,000	102,654
2007	6,900	6,500	4,800	5,300	23,500	126,154
2008	7,900	7,000	4,000	5,500	24,400	150,554
2009	8,900	8,000	4,500	5,800	27,200	177,754
2010	11,000	8,500	4,500	6,000	30,000	207,754

TABLE 2
HDTV RECEIVER
WORLDWIDE SALES FORECAST
(IN MILLIONS OF U.S. DOLLARS)

DATE	U.S.	WESTERN EUROPE	JAPAN	R.O.W.	TOTAL	CUMULATIVE TOTAL
1990	$4	$4	$80	$4	$92	$92
1991	$18	$4	$280	$10	$314	$406
1992	$25	$7	$480	$10	$522	$928
1993	$29	$9	$754	$15	$806	$1,734
1994	$54	$14	$945	$16	$1,028	$2,762
1995	$75	$14	$1,125	$25	$1,238	$4,001
1996	$176	$22	$1,364	$32	$1,594	$5,595
1997	$200	$100	$1,600	$40	$1,940	$7,535
1998	$450	$270	$1,800	$54	$2,574	$10,109
1999	$800	$480	$1,920	$160	$3,360	$13,469
2000	$1,500	$1,500	$2,400	$1,050	$6,450	$19,919
2001	$2,080	$1,950	$2,600	$1,560	$8,190	$28,909
2002	$2,860	$2,640	$3,300	$2,090	$10,890	$38,999
2003	$4,900	$3,000	$3,500	$2,500	$13,900	$52,899
2004	$5,850	$4,050	$4,050	$3,060	$17,010	$69,909
2005	$5,360	$4,000	$4,000	$3,200	$16,560	$86,469
2006	$5,100	$4,125	$3,750	$3,525	$16,500	$102,969
2007	$4,830	$4,550	$3,360	$3,710	$16,450	$119,418
2008	$5,135	$4,550	$2,600	$3,575	$15,860	$135,279
2009	$5,563	$5,000	$2,813	$3,625	$17,000	$152,279
2010	$6,600	$5,100	$2,700	$3,600	$18,000	$170,279

Note: HDTV market values are based on expected retail prices for an HDTV receiver, excluding local taxes:

> Pricing is estimated to start at $4,000 in 1990 for early units; dropping to $2,500 in the year 1995; $1,500 in the year 2000; $800 in the year 2005; and $600 in the year 2010.

MIT studies suggest that consumers are likely to be very price sensitive in purchasing ATV-HDTV sets over present low cost NTSC type. If technological innovation--for example in displays, projection equipment, etc.--brings down initial cost, market penetration will be faster.

HDTV VCR: TABLES 3 AND 4

Assumptions

(1) HDTV VCR sales to consumers are expected to start in 1990 in Japan along with sales of HDTV receivers. The forecast for HDTV VCR Worldwide Sales in Tables 3 and 4 include home decks only, not camcorders.

(2) EDTV VCR decks in the U.S. and Europe are counted in Tables 3 and 4 as HDTV VCRs, because it is assumed they will have the capability of being upgraded for HDTV recording.

TABLE 3
HDTV VIDEO CASSETTE RECORDER WORLDWIDE SALES FORECAST

(IN THOUSANDS OF UNITS)

DATE	U.S.	WESTERN EUROPE	JAPAN	R.O.W.	TOTAL	CUMULATIVE TOTAL
1990	1	0	20	C	21	21
1991	4	1	40	1	46	67
1992	8	1	120	1	130	197
1993	10	2	200	2	214	411
1994	12	23	300	3	318	729
1995	15	23	400	3	421	1,150
1996	40	5	600	5	650	1,800
1997	80	20	750	7	857	2,657
1998	200	30	900	10	1,140	3,797
1999	400	250	1,100	20	1,770	5,567
2000	800	800	1,400	50	3,050	8,617
2001	1,300	1,300	1,800	350	4,750	13,367
2002	2,100	1,750	2,500	600	6,950	20,317
2003	4,000	2,380	3,000	1,000	10,380	30,697
2004	5,200	2,150	4,000	1,200	12,550	43,247
2005	5,500	3,200	4,200	1,700	14,600	57,847
2006	5,600	3,750	4,500	2,000	15,850	73,697
2007	6,000	4,200	4,000	3,000	17,200	90,897
2008	6,500	4,500	4,000	3,500	18,500	109,397
2009	7,200	4,700	3,500	4,000	19,400	128,797
2010	9,000	5,000	3,200	5,000	22,200	150,997

TABLE 4
HDTV VIDEO CASSETTE RECORDER WORLDWIDE SALES FORECAST
(IN MILLIONS OF U.S.D.)

DATE	U.S.	WESTERN EUROPE	JAPAN	R.O.W.	TOTAL	CUMULATIVE TOTAL
1990	$2	$0	$40	$0	$42	$42
1991	$7	$2	$72	$2	$83	$125
1992	$13	$2	$192	$2	$208	$333
1993	$14	$3	$280	$3	$301	$634
1994	$16	$4	$390	$4	$413	$1,047
1995	$18	$4	$480	$4	$506	$1,553
1996	$44	$6	$660	$6	$715	$2,268
1997	$84	$21	$788	$7	$900	$3,167
1998	$200	$30	$900	$10	$1,140	$4,307
1999	$380	$238	$1,045	$19	$1,682	$5,989
2000	$720	$720	$1,260	$45	$2,745	$8,734
2001	$1,105	$1,105	$1,530	$298	$4,038	$12,771
2002	$1,680	$1,400	$2,000	$480	$5,560	$18,331
2003	$3,000	$1,785	$2,250	$750	$7,785	$26,116
2004	$3,640	$1,505	$2,800	$840	$8,785	$34,901
2005	$3,575	$2,080	$2,730	$1,105	$9,490	$44,391
2006	$3,360	$2,250	$2,700	$1,200	$9,510	$53,901
2007	$3,300	$2,310	$2,200	$1,650	$9,460	$63,361
2008	$3,413	$2,363	$2,100	$1,838	$9,713	$73,074
2009	$3,600	$2,350	$1,750	$2,000	$9,700	$82,774
2010	$4,275	$2,375	$1,520	$2,375	$10,545	$93,319

Note: Prices for HDTV video cassette recorders forecast in Table 4 are expected retail prices:

> Pricing for an HDTV VCR is estimated to start at $2,000 in 1990 for early units; dropping to $1,200 in the year 1995; $900 in the year 2000; $650 in the year 2005; and $480 in the year 2010.

COLOR TV: Table 5

Assumptions

(1) Table 5 includes all types of color TVs expected to be sold in the U.S.--NTSC, IDTV, EDTV and HDTV.

(2) Improved Definition (IDTV) sets, introduced prior to 1990, that receive only standard NTSC transmissions are included with figures for standard NTSC sets.

(3) Sales of Enhanced Definition (EDTV) sets, all of which are fully compatible with standard NTSC, are assumed to start in 1993 when the EDTV broadcasts are likely to begin.

(4) Compatible evolutionary HDTV broadcasts are assumed to start in 1996, giving rise to sales of HDTV receivers from that year forward. These sets will likely receive standard NTSC, EDTV, and HDTV transmissions or alternative delivery systems.

(5) Small sales of 1125/60 monitors and receivers, mainly to professional users rather than consumers, are assumed to occur prior to the start of transmissions via locally agreed EDTV/HDTV standards.

TABLE 5
COLOR TV (ALL)
U.S. MARKET FORECAST
(IN MILLIONS OF UNITS AND BILLIONS OF U.S.D.)

DATE	TOTAL UNITS	STANDARD NTSC/IDTV UNITS	STANDARD NTSC/IDTV $BN	EDTV UNITS	EDTV $BN	HDTV UNITS	HDTV $BN	TOTAL MKT VALUE	CUM. TOTAL VALUE
1990	22.9	22.9	$8.7	*		*		$8.7	$8.7
1991	24.0	24.0	$9.8	*		*		$9.8	$18.5
1992	24.0	24.0	$10.5	*		*		$10.5	$29.0
1993	23.5	23.3	$10.2	0.2	$0.3	*		$10.5	$39.5
1994	23.3	22.9	$10.1	0.4	$0.5	*	$0.1	$10.7	$50.2
1995	23.3	22.3	$9.8	1.0	$1.0	*	$0.1	$10.9	$61.1
1996	23.5	21.4	$8.8	2.0	$2.0	0.1	$0.2	$11.0	$72.1
1997	24.0	20.3	$8.3	3.6	$3.2	0.1	$0.2	$11.7	$83.8
1998	24.2	19.1	$7.3	4.8	$4.3	0.3	$0.5	$12.0	$95.8
1999	24.5	16.7	$6.3	7.3	$6.6	0.5	$0.8	$13.7	$109.5
2000	24.7	14.7	$5.6	9.0	$8.1	1.0	$1.5	$15.2	$124.7
2001	25.0	12.4	$4.7	11.0	$9.4	1.6	$2.1	$16.2	$140.9
2002	25.3	10.3	$3.6	12.4	$10.5	2.6	$2.9	$17.0	$157.9
2003	25.5	8.4	$2.9	12.2	$9.8	4.9	$4.9	$17.6	$175.5
2004	25.7	7.2	$2.5	12.0	$9.7	6.5	$5.9	$18.1	$193.6
2005	25.9	6.2	$2.0	13.0	$9.7	6.7	$5.4	$17.1	$210.7
2006	26.2	6.0	$1.9	13.4	$9.7	6.8	$5.1	$16.7	$227.4
2007	26.5	5.0	$1.6	14.6	$9.5	6.9	$4.8	$15.9	$243.3
2008	26.7	5.0	$1.6	13.8	$6.9	7.9	$5.1	$13.6	$256.9
2009	27.0	5.0	$1.6	13.1	$6.5	8.9	$5.6	$13.7	$270.6
2010	27.2	4.2	$1.3	12.0	$5.4	11.0	$6.6	$13.3	$283.9

* Less than 100,000 units per annum (see Table 1)

SEMICONDUCTOR VALUE IN COLOR TVS:TABLE 6

The value of semiconductors in all types of Color TVs sold worldwide is several times the total numbers offered in Table 6. To be conservative, however, Table 6 is limited to the U.S. market, reflecting the view that U.S. HDTV product manufacturers will have the greatest potential to sell into the U.S. market. If the U.S. is successful at being a major player in its own market, significant international sales opportunities will develop which are not forecast here.

The semiconductor value in all types of Color TVs, both integrated circuit and discrete, which are sold in the U.S. have been made in Table 6 under the following assumptions:

Assumptions

(1) Average semiconductor value also includes non-recurring engineering development costs for VLSI circuits for EDTV and HDTV systems.

(2) Average semiconductor value rises for standard NTSC/IDTV category due to higher content of IDTV receivers in the total. It falls in later years as EDTV and HDTV take over, and the IDTV content in mix of sets declines --as does the cost of IDTV integrated circuits.

TABLE 6
COLOR TV (ALL)
ASC/TV (AVERAGE SEMICONDUCTOR VALUE PER TV RECEIVER) U.S. MARKET FORECAST

(IN MILLIONS OF UNITS AND U.S.D.)
(TOTAL AND CUMULATIVE TOTAL IN MILLIONS OF U.S.D.)

		STANDARD NTSC/IDTV		EDTV		HDTV			
DATE	TOTAL UNITS	UNITS	USD	UNITS	USD	UNITS	USD	TOTAL MKT VALUE	CUM. TOTAL VALUE
1990	22.9	22.9	$29	*		*		$664	$664
1991	24.0	24.0	$30	*		*		$720	$1,384
1992	24.0	24.0	$31	*		*	$250	$746	$2,130
1993	23.5	23.3	$33	0.2	$140	*	$220	$799	$2,929
1994	23.3	22.9	$35	0.4	$120	*	$195	$853	$3,782
1995	23.3	22.3	$35	1.0	$110	*	$175	$896	$4,678
1996	23.5	21.4	$35	2.0	$100	0.1	$152	$961	$5,639
1997	24.0	20.3	$34	3.6	$90	0.1	$132	$1,027	$6,667
1998	24.2	19.1	$32	4.8	$80	0.3	$117	$1,025	$7,691
1999	24.5	16.7	$30	7.3	$70	0.5	$102	$1,063	$8,754
2000	24.7	14.7	$28	9.0	$65	1.0	$97	$1,094	$9,848
2001	25.0	12.4	$27	11.0	$60	1.6	$92	$1,142	$10,990
2002	25.3	10.3	$27	12.4	$55	2.6	$87	$1,186	$12,176
2003	25.5	8.4	$26	12.2	$50	4.9	$82	$1,230	$13,406
2004	25.7	7.2	$25	12.0	$50	6.5	$77	$1,281	$14,687
2005	25.9	6.2	$24	13.0	$48	6.7	$72	$1,255	$15,942
2006	26.2	6.0	$23	13.4	$48	6.8	$67	$1,237	$17,179
2007	26.5	5.0	$22	14.6	$47	6.9	$62	$1,224	$18,403
2008	26.7	5.0	$22	13.8	$47	7.9	$62	$1,248	$19,651
2009	27.0	5.0	$22	13.1	$47	8.9	$62	$1,278	$20,929
2010	27.2	4.2	$22	12.0	$47	11.0	$62	$1,356	$22,285

* Less than 100,000 units per annum (see Table 1)

VCR: TABLE 7

Assumptions

(1) All types of home VCR decks are included:
--Current VCRs that record only standard NTSC;
--EDTV/NTSC VCRs, assumed to be introduced in 1993;
--HDTV/EDTV/NTSC VCRs, assumed to be introduced in 1996.

(2) Small sales of 1125/60 HDTV VCRs, assumed to occur prior to start-up of local standard EDTV/HDTV services. are shown in Table 7 but not Table 8. [See Tables 3 and 4 for years prior to 1996.]

(3) Pre-recorded EDTV and HDTV videocassettes are assumed to become widely available in an extensive range of popular titles through rental outlets once the VCR population exceeds two million for each system. Availability of these videocassetts will likely further stimulate market growth.

TABLE 7
VIDEO CASSETTE RECORDER (ALL)
U.S. MARKET FORECAST
(IN MILLIONS OF UNITS AND BILLIONS OF U.S.D.)

DATE	TOTAL UNITS	STANDARD NTSC UNITS	STANDARD NTSC USD	NTSC/EDTV UNITS	NTSC/EDTV USD	NTSC/EDTV & HDTV UNITS	NTSC/EDTV & HDTV USD	TOTAL MKT VALUE	CUM. TOTAL VALUE
1990	11.0	11.0	$2.8	*		*		$2.8	$2.8
1991	11.5	11.5	$2.8	*		*		$2.8	$5.6
1992	11.5	11.5	$2.8	*		*		$2.8	$8.4
1993	12.1	12.0	$3.0	0.1	$0.1	*		$3.1	$11.5
1994	12.3	12.0	$3.0	0.3	$0.3	*		$3.3	$14.8
1995	11.8	11.0	$2.8	0.8	$0.6	*		$3.4	$18.2
1996	11.5	10.0	$2.3	1.5	$1.2	*		$3.5	$21.7
1997	11.6	9.0	$2.0	2.5	$2.0	0.1	$0.1	$4.1	$25.8
1998	11.8	8.0	$1.6	3.6	$2.5	0.2	$0.2	$4.3	$30.1
1999	11.6	6.0	$1.2	5.2	$3.1	0.4	$0.4	$4.7	$34.8
2000	12.0	4.0	$0.7	7.2	$3.6	0.8	$0.8	$5.0	$39.8
2001	13.0	3.0	$0.5	8.7	$3.5	1.3	$1.1	$5.1	$44.9
2002	11.8	1.5	$0.2	8.2	$2.4	2.1	$1.7	$4.3	$49.2
2003	12.5	0.5	$0.1	8.0	$2.4	4.0	$3.0	$5.5	$54.7
2004	12.2			6.8	$2.4	5.2	$3.6	$6.0	$60.7
2005	12.0			6.5	$2.0	5.5	$3.6	$5.6	$66.3
2006	12.0			6.4	$1.9	5.6	$3.4	$5.3	$71.6
2007	12.0			6.0	$1.8	6.0	$3.3	$5.1	$76.7
2008	12.0			5.5	$1.4	6.5	$3.4	$4.8	$81.5
2009	12.0			4.8	$1.2	7.2	$3.6	$4.8	$86.3
2010	12.0			3.0	$0.1	9.0	$4.3	$5.1	$91.4

HDTV RECEIVER & VCR: TABLE 8

Table 8 reflects combined numbers from Table 2 and Table 4 to provide a view of the size of the total U.S. HDTV Receiver-VCR target market available for penetration. A variety of market penetration perspectives are offered. However, 20 percent to 30 percent market penetration by U.S. firms would be optimistic.

TABLE 8
U.S. HDTV RECEIVER AND VCR COMBINED SALES FORECAST

(IN MILLIONS OF U.S.D.)

YEAR	U.S. MARKET	U.S. HDTV PRODUCT MANUFACTURERS' MARKETSHARE				
		50%	40%	30%	20%	10%
1990	$6	$3	$2	$2	$1	$1
1991	$25	$12	$10	$7	$5	$2
1992	$38	$19	$15	$11	$8	$4
1993	$43	$22	$17	$13	$9	$4
1994	$70	$35	$28	$21	$14	$7
1995	$93	$47	$37	$28	$19	$9
1996	$220	$110	$88	$66	$44	$22
1997	$284	$142	$114	$85	$57	$28
1998	$650	$325	$260	$195	$130	$65
1999	$1,180	$590	$472	$354	$236	$118
2000	$2,220	$1,110	$888	$666	$444	$222
2001	$3,185	$1,593	$1,274	$956	$637	$319
2002	$4,540	$2,270	$1,816	$1,362	$908	$454
2003	$7,900	$3,950	$3,160	$2,370	$1,580	$790
2004	$9,490	$4,745	$3,796	$2,847	$1,898	$949
2005	$8,935	$4,468	$3,574	$2,681	$1,787	$894
2006	$8,460	$4,230	$3,384	$2,538	$1,692	$846
2007	$8,130	$4,065	$3,252	$2,439	$1,626	$813
2008	$8,548	$4,274	$3,419	$2,564	$1,710	$855
2009	$9,163	$4,581	$3,665	$2,749	$1,833	$916
2010	$10,875	$5,438	$4,350	$3,263	$2,175	$1,088
TOTALS	$84,055	$42,028	$33,622	$25,217	$16,811	$8,406

SECTION III

RELATED INDUSTRY MARKET SALES PROJECTIONS

HDTV technology will affect most electronics industry segments -- it just depends when. Any number of products could have been selected for HDTV market impact forecast. Report deadlines constrained amount of information to be obtained and analyzed; however, so three product areas are included herein: automated manufacturing equipment, personal computers, and semiconductors.

Each was selected because foreign-market domination of HDTV product manufacturing will likely:

- Cause substantial investment in foreign-made Automated Manufacturing Equipment by a wide variety of foreign manufacturers, thereby increasing foreign domination in automated manufacturing equipment worldwide.

  It should be noted that prior to 1970, the U.S. sold close to 100 percent of the worldwide market for automated manufacturing equipment, versus 35 percent today. During the same timeframe, Asia has increased to 42 percent, Western Europe to 20 percent, and Rest of World (ROW) to 3 percent.

- Enable the Japanese and Koreans to perfect their marketing, engineering, and manufacturing skills to produce a world-class Personal Computer, thereby continuing to gain marketshare in the personal computer industry at the expense of U.S.-owned companies.

  It should be noted that prior to 1983, the U.S. sold 72.4 percent of the worldwide market for personal computers, versus 69.1 percent in 1987. During the same timeframe, Japan has increased from 17.5 percent to 17.6 percent, and Western Europe has increased from 9.3 percent to 9.8 percent.

- Deal a critical blow that cripples the U.S. Semiconductor industry, as substantial sales are lost to marketing domination in the personal computer industry by foreign manufacturers who purchase primarily, if not totally, foreign-made semiconductors.

  It should be noted that prior to 1983, the U.S. sold 49 percent of the worldwide market for semiconductors, versus 39.3 percent in 1987. During the same timeframe, Japan has increased from 38.8 percent to 47.9 percent, and Western Europe has decreased from 11.3 percent to 11.1 percent.

General Assumptions for Tables 9, 10, 11

(1) Figures in Tables 9, 10, 11 reflect perspective of not only direct impact but indirect impact of U.S. companies participation or non-participation in HDTV.

Indirect Impact

-- In Table 11: Semiconductors, for example, direct loss of sales to U.S. semiconductor manufacturers if the U.S. does not participate in the U.S. HDTV market is approximately $3 billion. However, if HDTV technology advances current technology so that non-players' semiconductor technology becomes obsolete, the U.S. as a non-HDTV player will lose its innovative edge and U.S. marketshare in non-HDTV markets as well (i.e., the indirect or "ripple effect.")

- Tables 9, 10, 11 also reflect the view that HDTV participants will significantly shorten their "learning curve" in leading edge technologies. For example, if U.S. manufacturers do not participate in HDTV, the products they presently design innovatively and in a shorter time frame may be done more innovatively and in a shorter time frame by foreign competitors who participate in HDTV.

- The point of emphasis is the direct link between who leads in innovation and who supplies key components. When U.S. manufacturers rely on foreign suppliers for key components, such as computer displays, they frequently lose their lead in innovation, engineering design, and domestic or international marketshare.

(2) Tables 9, 10, 11 figures were derived by first collecting perspectives of HDTV impact on U.S. marketshare by the year 2010 from experienced industry analysts and company executives, averaging them, and then phasing in the impact on an equal basis each year beginning in 1991.

AUTOMATED MANUFACTURING EQUIPMENT: TABLE 9

The Automated Manufacturing Equipment forecast in Table 9 includes a wide variety of products, including robotics, process control equipment, and computers installed specifically for manufacturing.

Assumptions

(1) U.S.-owned automated manufacturing equipment manufacturers hold an average in 1990 of 35 percent of the world market.

(2) Projections for growth were done using a constant compound annual growth rate of ten percent for the years beyond 1991.

(3) U.S. manufacturers marketshare of worldwide sales without HDTV impact will remain constant until the year 2010 at 35 percent; this is viewed by some as an optimistic assumption. Industry estimates are that presently all of Asia holds 42 percent of worldwide sales, with Western Europe at 20 percent and the Rest of the World at 3 percent.

(4) If U.S.-owned firms are limited to a "weak" position [10 percent or less] of the U.S. market for HDTV products, then U.S. owned manufacturers of automated manufacturing equipment stand to lose approximately 20 percent of their present worldwide marketshare. This will decrease their world marketshare in the year 2010 to 28 percent, a loss of $8 billion.

(5) If U.S.-owned firms are able to obtain a "strong" position [50 percent or more] of the U.S. market for HDTV products, then U.S.-owned manufacturers of automated manufacturing equipment stand to gain approximately 20 percent more than their 35 percent present worldwide marketshare. This would increase their worldwide share to 42 percent, a gain of $8 billion in the year 2010 alone.

TABLE 9
AUTOMATED MANUFACTURING EQUIPMENT U.S. MANUFACTURERS' MARKETSHARE OF WORLDWIDE SALES IF U.S. HDTV MANUFACTURERS CAPTURE 10-50% OF U.S. HDTV MARKET

(IN MILLIONS OF U.S.D.)

YEAR	WORLDWIDE AUTO. MAN. SALES (W/O HDTV) (IMPACT)	REST OF THE WORLD MKTSHARE (W/O HDTV) (IMPACT)	U.S. MAN. MKTSHARE WW SALES (W/O HDTV) (IMPACT)	WHAT HAPPENS TO U.S. A.M.E. MANUFACTURERS' MARKETSHARE IF U.S. HDTV MANUFACTURERS' ARE:		
				STRONG	MEDIUM	WEAK
1990	$21,613	$14,048	$7,565	$7,565	$7,565	$7,565
1991	$23,542	$15,302	$8,240	$8,322	$8,240	$8,157
1992	$25,572	$16,622	$8,950	$9,129	$8,950	$8,771
1993	$27,780	$18,057	$9,723	$10,015	$9,723	$9,431
1994	$30,182	$19,618	$10,564	$10,986	$10,564	$10,141
1995	$32,795	$21,317	$11,478	$12,052	$11,478	$10,904
1996	$35,639	$23,165	$12,474	$13,222	$12,474	$11,725
1997	$38,736	$25,178	$13,558	$14,506	$13,557	$12,608
1998	$42,104	$27,368	$14,736	$15,915	$14,736	$13,558
1999	$45,773	$29,752	$16,021	$17,462	$16,021	$14,579
2000	$49,769	$32,350	$17,419	$19,161	$17,419	$15,677
2001	$54,121	$35,179	$18,942	$21,026	$18,942	$16,859
2002	$58,863	$38,261	$20,602	$23,074	$20,602	$18,130
2003	$64,030	$41,620	$22,411	$25,324	$22,410	$19,497
2004	$69,662	$45,280	$24,382	$27,795	$24,382	$20,968
2005	$75,803	$49,272	$26,531	$30,511	$26,531	$22,551
2006	$82,499	$53,624	$28,875	$33,495	$28,875	$24,255
2007	$89,804	$58,373	$31,431	$36,775	$31,432	$26,088
2008	$97,775	$63,554	$34,221	$40,381	$34,221	$28,601
2009	$106,475	$69,209	$37,266	$44,347	$37,266	$30,186
2010	$115,973	$75,382	$40,591	$48,700	$40,590	$32,472
	(100%)	(65%)	(35%)	(42%)	(35%)	(28%)

MARKETSHARE PROJECTIONS IN PERCENTAGES FOR 2010

PERSONAL COMPUTER: TABLE 10

Personal computer forecast in Table 10 includes a wide variety of desktop computers, such as IBM, Apple, Compaq, DEC, Tandy, and many others.

Assumptions

(1) U.S.-owned personal computer manufacturers hold an average of 70 percent of the world market.

(2) Projections for growth were done using a constant compound annual growth rate of ten percent for the years beyond 1988.

(3) U.S. manufacturers marketshare of worldwide sales will remain constant at 70 percent;this is view by some as optimistic. Industry estimates are that presently Japan holds 17 percent of worldwide sales, with Western Europe at 9 percent and the Rest of the World at 4 percent.

(4) These estimates do not reflect U.S.-owned companies that merely private-label personal computers that are made by foreign firms, nor the high content in all personal computers of components made by foreign companies (floppy drives, semiconductors, cases, monitors, etc.) in plants located outside the U.S.

(5) If they have a dominant HDTV position, the Japanese will leverage what they learn in designing, engineering, and manufacturing HDTV products to take substantial marketshare away from U.S. personal computer manufacturers.

(6) If U.S.-owned firms are able to obtain a "strong" position [50 percent or more] in the U.S. market for HDTV products, then U.S.-owned personal computer manufacturers stand to hold their current world marketshare of 70 percent.

(7) If U.S.-owned firms are limited to a "weak" position [10 percent or less] of the U.S. market for HDTV products, then U.S.-owned personal computer manufacturers stand to lose approximately 50 percent of their present marketshare worldwide. This would decrease their worldwide share to 35 percent, a loss of $110 billion dollars in the year 2010 alone.

It is important to recognize that although today U.S. personal computer manufacturers enjoy a substantially larger marketshare than their foreign trading partners, this lead is declining. Storeboard Inc. a market research firm that tracks domestic retail sales of personal computers in the September 13, 1988 issue of PC WEEK reported:

> July (sales) figures showed Japanese and Korean PC manufacturers gaining market share at the expense of IBM and Apple Computer. . . . Marketshare owned by manufacturers from those two Asian nations grew from 14.6 percent in July 1987 to 18 percent this July 1988.

Many agree that in the next ten years HDTV receivers/VCRs will be able to connect to 100MB of data storage, a variety of floppy disk drives, printers, fax machines, telephones, and many other products and enhancements. As this takes place, the U.S. personal computer industry will be faced with its most significant marketing challenge. This challenge will be twofold:

1) Sophisticated HDTV products may compete with home personal computers for consumer dollars.

2) More significantly, Table 10 assumes that if the Japanese virtually own the HDTV industry, their HDTV engineering, consumer product research, and marketing will enable them to greatly increase their ability to manufacture a variety of personal computers with substantial consumer appeal and acceptance.

TABLE 10
PERSONAL COMPUTER
U.S. MANUFACTURERS' MARKETSHARE OF WORLDWIDE SALES IF U.S. HDTV MANUFACTURERS CAPTURE 10-50% OF U.S. HDTV MARKET

(IN MILLIONS OF U.S.D.)

YEAR	WORLDWIDE PC MAN. SALES (W/O HDTV) (IMPACT)	REST OF THE WORLD MKTSHARE (W/O HDTV) (IMPACT)	U.S. MAN. MKTSHARE WW SALES (W/O HDTV) (IMPACT)	WHAT HAPPENS TO U.S. PC MANUFACTURERS' MARKETSHARE IF U.S. HDTV MANUFACTURERS' ARE:		
				STRONG	MEDIUM	WEAK
1990	$48,400	$14,520	$33,880	$33,880	$27,104	$16,940
1991	$52,200	$15,660	$36,540	$36,540	$29,232	$18,270
1992	$56,700	$17,010	$39,690	$39,690	$31,752	$19,845
1993	$62,300	$18,690	$43,610	$43,610	$34,888	$21,805
1994	$68,600	$20,580	$48,020	$48,020	$38,416	$24,010
1995	$75,400	$22,620	$52,780	$52,780	$42,224	$26,390
1996	$83,000	$24,900	$58,100	$58,100	$46,480	$29,050
1997	$91,200	$27,360	$63,840	$63,840	$51,072	$31,920
1998	$100,400	$30,120	$70,280	$70,280	$56,224	$35,140
1999	$110,400	$33,120	$77,280	$77,280	$61,824	$38,640
2000	$121,500	$36,450	$85,050	$85,050	$68,040	$42,525
2001	$133,600	$40,080	$93,520	$93,520	$74,816	$46,760
2002	$147,000	$44,100	$102,900	$102,900	$82,320	$51,450
2003	$161,700	$48,510	$113,190	$113,190	$90,552	$56,595
2004	$177,800	$53,340	$124,460	$124,460	$99,568	$62,230
2005	$195,600	$58,680	$136,920	$136,920	$109,536	$68,460
2006	$215,200	$64,560	$150,640	$150,640	$120,512	$75,320
2007	$236,700	$71,010	$165,690	$165,690	$132,552	$82,845
2008	$260,300	$78,090	$182,210	$182,210	$145,768	$91,105
2009	$286,400	$85,920	$200,480	$200,480	$160,384	$100,240
2010	$315,000	$94,500	$220,500	$220,500	$176,400	$110,250
	(100%)	(30%)	(70%)	(70%)	(56%)	(35%)

MARKETSHARE PROJECTIONS IN PERCENTAGES FOR 2010

SEMICONDUCTOR: TABLE 11

Although there are many important industry product segments to be impacted by HDTV technology, most agree that semiconductors are the most strategically important to the U.S.

The Japanese have taken a significant lead in developing faster, more compact IC packaging technology and "driver" integrated circuits (ICs)--virtually all of which are made outside the U.S. Two critical areas in which the U.S. must maintain its lead are in computer technology and defense systems.

Even before the introduction of HDTV, memory consumption in digital feature TV and IDTV will approach that consumed by personal computers on a worldwide basis by 1991, and easily surpass it by the mid-1990s.

The fact that the Japanese dominate the DRAM market today will have increasingly significant impact as the memory consumption of television products surpasses personal computers. This is in part because, although a personal computer's DRAMs must be absolutely perfect, a DRAM for a television receiver does not.

For instance, a personal computer manufacturer cannot use a DRAM with any imperfection, because it would create incorrect bits in a computer application. However, that same DRAM--defective for personal computers--is suitable for television, where it would only impair a pixel or two.

> The consequences of a few inaccurate pixels are not anywhere near the drastic imperfection of incorrect bits in a computer application. Thus, vertically integrated Japanese producers may have an outlet for up to 10 percent of their DRAM production that is currently being scrapped. This would significantly lower their overall costs and be another edge over U.S. DRAM manufacturers and purchasers, such as U.S. personal computer companies.

To consider the impact of HDTV on the U.S. semiconductor industry, it is helpful to understand the current breakdown of U.S. semiconductor manufacturers' sales in the U.S:

Market	Percent
Communications	11.0%
Computer	44.4%
Consumer	6.4%
Government	12.5%
Industrial	15.3%
Transportation	10.4%

Because the large HDTV market will allow the Japanese to rapidly descend their learning curves, they can easily keep the U.S. and other foreign competitors out of the markets for vital semiconductors--as occurred in the last decade in CMOS circuitry and CCD (charge-coupled device).

Furthermore, U. S. semiconductor manufacturers will be in an increasingly weak position to sell into overseas markets or to get their products designed into HDTV products that are built in the U.S. by foreign-owned manufacturers.

In turn, this significant lost business also reduces the ability of U.S. semiconductor manufacturers to compete effectively in other End Use equipment sectors, such as personal computers.

Thus, semiconductor projections in Table 11 follow the same trend line as to projections for personal computers in Table 10, only more so. If the U.S. loses its substantial lead in personal computers, it follows that this will severely impact the U.S. semiconductor industry.

Although volume is the major concern long-term, it is not the primary concern of the U.S. semiconductor relative to HDTV. Engineering innovation is the overriding issue.

In mid-1988, several managers from a top U.S. semiconductor firm were able to preview the 40 chip set for HDTV receivers that has been developed by a Japanese firm. Validation that these chips already existed--a concern the U.S. executives had feared-- was greatly overshadowed by realization that their engineers probably did not even know how to engineer the chips. The level of sophistication in consumer electronics had taken another quantum leap forward.

Presently, only 6 percent of U.S. semiconductor output compared to 50 percent of Japan's semiconductor output is used in consumer electronics products. Without a major U.S.-controlled presence, the economies of scale provide by this new HDTV market are likely to drastically reduce the current worldwide share enjoyed by U.S. semiconductor manufacturers.

It was the unanimous consensus of every industry executive interviewed that the minor sales into the consumer products market by U.S semiconductor manufacturers is one of the primary reasons they are currently struggling in virtually all markets worldwide.

Worldwide sales of semiconductors into consumer electronics products are estimated to be at least $10 billion in 1988. If the U.S. does not participate in the HDTV market, everyone surveyed is concerned the U.S. could lose any current technological superiority it has in other markets as semiconductor products designed for consumer electronics--including HDTV--broaden their applications into other significant End Use markets.

Such a trend has grown recently because of the increased use of digital circuits in consumer applications. This makes the lack of participation by U.S. companies in consumer electronics even more critical as these digital circuits can also be used easily for industrial applications such as computers and telecommunications.

This technological edge question is further compounded because the manufacturing expertise in high-volume, low cost, high reliability consumer parts is directly applicable to smaller volume, industrial applications. Therefore, the odds are significantly in favor of the market leader(s) in high volume semiconductors eventually dominating the markets for smaller volume semiconductors.

The impact of HDTV technology on U.S. semiconductor manufacturers is straightforward:

> U.S. semiconductor manufacturers will be excluded or reduced to a very small marketshare of the very large HDTV market unless U.S.-owned manufacturers of HDTV products exist and unless they purchase componentry from U.S. semiconductor manufacturers.

The European community may be more likely than the Japanese to buy U.S. semiconductors, because of the European weakness in semiconductor production.

The consensus of those interviewed agreed that without a reasonable participation in the HDTV marketplace by U.S. manufacturers, the outlook for the U.S. semiconductor industry is bleak.

TABLE 11 ASSUMPTIONS:

Assumptions

(1) U.S.-owned semiconductor manufacturers hold an average of 41 percent of the world market.

(2) Projections of growth without HDTV impact were made using industry projections through 1991; these were then grown annually through the year 2000 at one rate per geographic region, and then another rate per geographic region from 2001 through 2010. These rates for the U.S. are 8 percent/7 percent; for Western Europe 7 percent/6 percent; for Japan 9 percent/8 percent; and for the Rest of World 13 percent/11 percent.

(3) U.S. manufacturers marketshare of worldwide sales will remain constant at 41 percent; this is viewed by many as optimistic. Industry estimates are that presently Japan holds 46 percent of worldwide sales, with Western Europe at 11 percent and the Rest of the World at 2 percent.

(4) If the Japanese attain a dominant HDTV position, they will likely leverage what they learn in designing, engineering, and manufacturing HDTV semiconductor products to take substantial marketshare away from U.S. semiconductor manufacturers in areas where the U.S. manufacturers have typically been strongest [e.g., national defense contracts, custom integrated circuits, and even processor technology.]

(5) If U.S.-owned firms are able to obtain a "strong" position [50 percent or more] in the U.S. market for HDTV products, then U.S.-owned semiconductor manufacturers stand to hold their current marketshare of 41 percent worldwide.

(6) If U.S.-owned firms are limited to a "weak" position [10 percent or less] of the U.S. HDTV market, U.S.-owned semiconductor manufacturers stand to lose approximately 50 percent of their present world marketshare. This would decreasing their world share to 20.5 percent, a loss of $62 B. in year 2010 alone.

TABLE 11
SEMICONDUCTOR - TOTAL SOLID STATE
U.S. MANUFACTURERS' MARKETSHARE OF WORLDWIDE SALES IF U.S. HDTV MANUFACTURERS CAPTURE 10-50% OF U.S. HDTV MARKET

(IN MILLIONS OF U.S.D.)

YEAR	WORLDWIDE SEMICNDCTR SALES (W/O HDTV) (IMPACT)	REST OF THE WORLD MKTSHARE (W/O HDTV) (IMPACT)	U.S. MAN. MKTSHARE WW SALES (W/O HDTV) (IMPACT)	WHAT HAPPENS TO U.S. SEMICONDUCTOR COMPANIES MKTSHRE IF U.S. HDTV MANUFACTURERS' ARE:		
				STRONG	MEDIUM	WEAK
1990	$49,005	$28,913	$20,092	$20,092	$16,074	$10,046
1991	$56,461	$33,312	$23,149	$23,149	$18,519	$11,575
1992	$61,766	$36,442	$25,324	$25,324	$20,259	$12,662
1993	$67,609	$39,889	$27,720	$27,720	$22,176	$13,860
1994	$74,049	$43,689	$30,360	$30,360	$24,288	$15,180
1995	$81,152	$47,880	$33,272	$33,272	$26,618	$16,636
1996	$88,993	$52,506	$36,487	$36,487	$29,190	$18,244
1997	$97,655	$57,616	$40,039	$40,039	$32,031	$20,019
1998	$107,232	$63,267	$43,965	$43,965	$35,172	$21,983
1999	$117,828	$69,519	$48,309	$48,309	$38,648	$24,155
2000	$129,562	$76,442	$53,120	$53,120	$42,496	$26,560
2001	$140,735	$83,034	$57,701	$57,701	$46,161	$28,851
2002	$152,946	$90,238	$62,708	$62,708	$50,166	$31,354
2003	$166,302	$98,118	$68,184	$68,184	$54,547	$34,092
2004	$180,917	$106,741	$74,176	$74,176	$59,341	$37,088
2005	$196,917	$116,181	$80,736	$80,736	$64,589	$40,368
2006	$214,442	$126,521	$87,921	$87,921	$70,337	$43,961
2007	$233,648	$137,852	$95,796	$95,796	$76,637	$47,898
2008	$254,706	$150,277	$104,429	$104,429	$83,544	$52,215
2009	$277,807	$163,906	$113,901	$113,901	$91,121	$56,950
2010	$303,160	$178,864	$124,296	$124,296	$99,436	$62,148
	(100%)	(59%)	(41%)	(41%)	(32.8%)	(20.5%)

MARKETSHARE PROJECTIONS IN PERCENTAGES FOR 2010

SECTION IV

THE COST TO BECOME A MAJOR HDTV MANUFACTURER

PRODUCT COST BREAKDOWN

The numbers in Table 12 provide a perspective on costs to manufacture a color television in 1987 by one of the largest assemblers in the U.S. The price to retailer includes a distributor margin. Note the 1 percent net profit margin, which illustrates the profitability problem.

TABLE 12
COLOR TV PRODUCTION COST BREAKDOWN: USA 1987
20" BASIC MODEL IN HIGH VOLUME

ITEM	$	%
COST TO DISTRIBUTOR (WHOLESALER**)	195	100
FACTORY DIRECT MARGIN	40	20.5
OF WHICH:		
VARIABLE MARKETING COST	10.5	5.4
FACTORY COSTS (E.G. LIGHTING)	12	6.2
OTHER BASE COSTS	15.5	7.9
OPERATING MARGIN	2	1
ROYALTIES	0.3	0.1
SCRAP	1.4	0.7
TOOLING	2.9	1.5
DIRECT LABOR COSTS		
ASSEMBLY	13.5	6.9
CHASSIS ASSEMBLY	25	12.8
OTHER MATERIALS (INCLUDING CABINET)	50	25.7
CRT	62	31.8

* These figures come from one of the largest Color TV assemblers in the U.S.

** The price to the retailer will include a distributor margin.

Note: Most HDTV receivers are expected to be primarily flat panel displays; however, the data available for this report reflects costs to manufacture or assemble cathode-ray tube units.

ENGINEERING

It is generally agreed that although the Japanese and Europeans have a significant lead in HDTV technology, the U.S. has the capability to catch-up rapidly *if* a major U.S. manufacturer or a consortium of U.S. manufacturers decides to participate in theHDTV market.

The following discussion of engineering costs are divided into three equipment areas: production, transmission, and receiver. Each poses its own set of challenges which will need to be overcome to get into HDTV manufacturing; however, none is viewed as insurmountable.

Production

Production equipment costs can be phased in over several years as existing production equipment becomes obsolete. The cost differential between NTSC and HDTV equipment is not expected to be substantial; therefore, HDTV costs are basically budgeted at today's figures.

Some assume that HDTV broadcasting will start with a couple of hours a day and that the number of hours will increase as the size of the audience grows. The major studios agree that eventually all production equipment will be HDTV.

The engineering costs to develop the equipment and to start initial production of products for FCC testing and field testing are separated into three areas: production equipment, receiver costs, and transmission equipment.

Production Equipment Costs

The lowest cost of developing the HDTV production equipment for studios is estimated at $10 million dollars over a three year period. The highest is in excess of $100 million.

Some of this wide difference in cost estimates may be attributed to the fact that there are no longer any U.S. manufacturers of studio production equipment components.

The Japanese are reputed to quote costs and delivery for these components, but not supply them. Conceivably, European companies could be a component source. If not, the costs of restarting studio production equipment component manufacturing might need to be considered.

Semiconductor Costs

Another scenario, which would add costs to the above estimates, would be for the U.S. to engineer its own custom semiconductors for U.S. HDTV equipment. Present Japanese HDTV systems contain approximately 40 custom-designed semiconductors. Some suggested U.S. designs envision up to 6 very large scale integrated circuits, which could be surface mounted--making viable cost-effective automated manufacturing.

The cost today to bring a semiconductor chip design from conception to the production stage is approximately $500,000 per chip. Therefore, to compete with a totally new U.S. design including custom semiconductors, another $20 million should be added to the expense.

Receiver Costs

To build a state-of-the-art HDTV receiver that can compete against the Japanese and other foreign firms will cost anywhere from $10 million to $100 million dollars. In addition, estimates to engineer studio, broadcast, and receiver technology run as high as $500 million dollars with a 3-5 year timeframe to complete.

Transmission Equipment Costs

Transmission equipment varies based on whether terrestrial or cable broadcast is planned.

The cost to implement a terrestrial transmission system is about $1.5 million per station. Cable costs only a few hundred thousand dollars per station.

THE TECHNOLOGY DRIVER

Basic to all television technology is the concept of the "technology driver" and the question of how to control it to advantage. A "technology driver" is a product that will itself be a major, multi-billion dollar market, and which, over the long term, will provide the manufacturer with a wide variety of spin-off markets. Some of these spin-off markets may be short term, others may be long term, but all can be extremely profitable and strategic.

For instance, color television was the technology driver essential for the advent of VCRs, camcorders, the video tape rental business, video games, etc.

If the U.S. intends to be a participant in the HDTV marketplace, therefore, it will need to control the technology driver inherent in HDTV technology. This will give U.S. manufacturers the opportunity to spin-off products, thereby controlling a majority marketshare of these products. With control of the technology driver also comes a thorough understanding of and opportunity to establish distribution for many of the spin-off markets.

Using the example of color television again, those companies who established significant distribution of color TVs were able to quickly enter the VCR and camcorder markets, etc. Many view this as one of the primary reasons Kodak failed in 8mm video camcorders. They did not have the infrastructure to support it, in spite of Kodak having immense distribution strength in the photographic sector.

In the past, large computers have been the driver for memory (RAM). Recently, a wide variety of desktop computers have increased the power of the computer market to be the driver for memory. HDTV will be the next significant consumer of memory. A typical Japanese TV in the 1990s may have as much as 1-2 megabytes of video RAM.

The advent of HDTV poses a significant threat, in particular, to the semiconductor industry because of all the memory and other semiconductor components that will be in HDTV equipment.

One of the key areas where color TV and eventually HDTV are primary technology drivers is flat panel color displays. Just as in the personal computer marketplace, the market for flat panel displays will likely top $730 million dollars by 1993. Already, Sharp (Japan) has announced it will have a 14-inch color (flat panel) TV on the market in 1989. Between 1.5 million and 2 million flat panel color TVs are expected to sell in Japan in 1988.

MITI has announced it has joined with a group of 12 Japanese companies (including Casio, Sharp, Hitachi, NEC, Sanyo and Seiko) to develop a 40 inch flat LCD color display by 1994 (on the market). Total investment is $74 million, with $52 million provided by MITI and the Post and Telecommunications Ministry.

MARKETING CONCEPT

HDTV is a significantly more expensive purchase-proposition for the consumer than standard color television. Substantial market penetration will be based primarily on getting total receiver costs down and identifying the best marketing concept--i.e., the one that convinces millions of consumers that they must have an HDTV receiver and VCR.

An example of a driving marketing concept is "time shifting" -- the key selling argument to own a VCR:

> "Now you can watch the football game at 2:00 a.m., after you dance the night away. If you don't have time to go to the movies during their regular scheduled hours, you can rent or buy the movie and watch whenever you please."

Some possibilities of the driving marketing concept that might sell HDTV include:

- "70 Inch Diagonal Projection TV! Revolutionary technology makes the picture as good as your familiar 19" portable TV! Project your favorite TV shows anywhere, anytime, anyplace. No bulky screens or poor picture quality! See beautiful quality pictures five feet high by three and a half feet wide! See your favorite television shows, movies and sporting events with incredible clarity and without a screen!"
- "FLAT TV is here! Full color 20" screen only one inch thick! Hang it on the wall. Enjoy brighter, higher resolution pictures than ever before. By day your TV screen is a Monet print. At the flick of a switch, this "picture" becomes the family entertainment center."

MANUFACTURING

The cost to set-up a facility to manufacture color picture displays and the cost to set-up a facility to assemble/manufacture color TV receivers is determined by the fact that no plant exists in the U.S. today capable of manufacturing an HDTV picture tube or flat panel display.

The world currently has a manufacturing overcapacity for color TVs, however. Plants are available for upgrading to manufacture HDTV products that use HDTV tubes. However, new tooling will be needed for HDTV flat panel displays. For example, Japan is investing $300+ million in 1988-1992 to upgrade their tooling from tube manufacturing to flat panel display, a joint venture of MITI and industry. In contrast, U.S. facilities primarily have cost savings when assembling HDTV products. They do not have the unique capabilities required to manufacture any type of display.

Note: Most HDTV receivers are expected to be primarily flat panel displays. Data available for this report, however, reflects costs to manufacture or assemble cathode-ray tube units.

Costs To Build A Display Plant

In March 1988, Matsushita (Japan) set-up the American Matsushita Company in Troy, Ohio to manufacture 29" and 33" color picture tubes. The company is capitalized at $100 million. Total investment in the facility is expected to reach $160 million, not including glass manufacturing. The cost of this plant would increase to approximately $500 million if it were to manufacture a wide variety of different size receivers.

The facility is on a "green field" site, which is projected to be operational in the spring of 1989. Initial production is targeted at 400,000 units increasing to full capacity of 1 million units within two years. Initially, the plant will employ 240 workers. By the time full production is reached, 400 people will be employed.

Costs To Build An Assembly Plant

Recently, two foreign companies have announced they will build new TV assembly plants--in Germany, Spain, and Alabama (U.S.):

- Goldstar (Korea) is building two plants -- one in Worms, Germany, estimated to cost $35 million, and the other in Huntsville, Alabama, expected to cost $50 million.
- Sharp (Japan) is building a plant in Barcelona, Spain, expected to cost $70 million.

Each of the plants has an approximate assembly production capacity of one million units per year.

Costs To Build A Manufacturing Plant

The Goldstar and Sharp plants described above are assembly operations, putting together a variety of components, the majority of which are from foreign plants.

To build an actual U.S. manufacturing plant would cost approximately $100-200 million. This plant would need to have the capacity to produce one million plus units per year. To get as much as 20% of the market, a company's plants would possibly have to produce possibly four million units per year.

It is suggested that investment in tooling is a better investment--not for traditional color TV manufacturing processes, but for leading-edge technology (i.e., active matrix flat panel displays and digital TV receivers, which are critical products for U.S. national defense.)

Television Manufacturing in the United States: Economic Contributions -- Past, Present, and Future

Prepared for the
Electronic Industries Association

Robert R. Nathan Associates, Inc.
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Industry Research and Analysis Group
Washington, D.C.

February 1989

FOREWORD

In 1987 the Electronic Industries Association recognized the need to examine and document the expansion of color TV manufacturing in the United States. At that time Robert R. Nathan Associates, Inc. (RRNA), was asked to determine the production and employment of television manufacturers in the United States and to estimate the tangible contributions of U.S. color television manufacturing since 1980. Thus, this report Television Manufacturing in the United States: Economic Contributions -- Past, Present and Future was conceived.

In addition, because of the rising interest in advanced television systems, RRNA was asked to assess the potential impact of high definition (HDTV) on U.S. color television manufacturing and sales.

As a result, in November 1988, Chapter IV, "High Definition TV's Potential Economic Impact on Television Manufacturing in the United States," was released. Chapters I, II, and III were released in March 1989.

TABLE OF CONTENTS

Chapter | Page

FOREWORD i

I. INTRODUCTION AND EXECUTIVE SUMMARY 1

Industry Background 3
Study Purpose 4
Study Methods 5

II. COLOR TV MANUFACTURING IN THE UNITED STATES 6

Survey Design 6
Production Activity 11
Plant Employment and Productivity 14

III. CONTRIBUTIONS OF COLOR TV MANUFACTURING TO THE U.S. ECONOMY 19

Estimating the Economic Impacts of TV Manufacturing 19
Growth and Development in Output, Value Added, and Employment 22
Economic Impact of TV Manufacturing by Source and Industry: 1987 28
Economic Impact of TV Manufacturing, by Location: 1987 36

IV. HIGH DEFINITION TV'S POTENTIAL ECONOMIC IMPACT ON TELEVISION MANUFACTURING IN THE UNITED STATES 46

HDTV Production and Sales Forecast 47
Impacts of HDTV on the U.S. TV Pipeline 64
Contributions of HDTV to the U.S. Economy 73
Conclusion 79

Appendix

A. ECONOMIC IMPACT OF COLOR TV MANUFACTURING: DETAILED DATA

B. HDTV FORECAST: DETAILED RESULTS

LIST OF TABLES

Table		Page
II-1.	U.S. Production and Total Factory Production, Units Produced and Production Value, 1980-1987	12
II-2.	U.S. Color TV Manufacturing Industry, Units Produced and Production Value, by Census Regions, 1980-1987	15
II-3.	U.S. Color TV Manufacturing Industry, Summary of Production, Factory Value, and Plant Employment (Production and Administrative Workers), 1980-1987	16
II-4.	U.S. Color TV Manufacturing Industry, Plant Employment, by Census Regions, 1980-1987	18
III-1.	Summary of Output, Value Added, and Employment, by Industry Group, 1980, 1985, and 1987	24
III-2.	Contributions of U.S. Color TV Manufacturing, Percent Change by Industry, 1980 to 1987	26
III-3	TV Receiver Set Manufacturing Industry, Value of Shipments and Value Added, Selected Years	29
III-4.	Summary of Output, Value Added, and Employment, Percent Distribution by Industry Group, 1980, 1985, and 1987	30
III-5.	Direct and Indirect Value Added and Employment Contribution of U.S. Color TV Manufacturing, by Industry, 1987	32
III-6.	Induced Value Added and Employment Contribution of U.S. Color TV Manufacturing, by Industry, 1987	35
III-7.	Value Added and Employment Contribution of U.S. Color TV Manufacturing, by Geographic Division and State, 1987	39
IV-1.	Market Shares, Average Retail Prices, Production Site, and Domestic Content of HDTV and NTSC Sets, if HDTV is Commercialized, by Screen Size, 1988 and 2003	53

LIST OF TABLES

(Continued)

Table Page

IV-2. Unit Sales, Average Retail Prices, Production Site, and Domestic Content of HDTV and NTSC Sets, in the Absence of HDTV Commercialization, by Screen Size, 1988 and 2003 56

IV-3. Forecast of Color TV and HDTV Unit Sales, Retail Value, U.S. Production, Retail Value of U.S Production, and Value Added by U.S. Production, Selected Years 58

IV-4. Projected HDTV Sales and U.S. Households, 1993 through 1998 62

IV-5. Comparison of U.S. Color TV Sales and Production With and Without HDTV Commercialization, 2003 63

IV-6. Employment in the TV Pipeline, Color TV in 1987 and HDTV in 2003 67

IV-7. U.S. Sales and U.S. Production of Color TVs, by Screen Size, 1988 through 2003 71

IV-8. Summary of the Contribution of the TV Receiver Set Manufacturing Industry to the U.S. Economy, 1987 75

IV-9. Economic Contributions of TV Manufacturing in the United States, 2003 78

A-1. Contributions of U.S. Color TV Manufacturing, by Industry, 1980, 1985, and 1987 81

A-2. Contributions of U.S. Color TV Manufacturing, by Census Region, Geographic Division, and State, 1987 82

B-1. Forecast of Color TV and HDTV Unit Sales, Retail Value, U.S. Production, 1989-2003 85

B-2. Forecast of Color TV Unit Sales, Retail Value, and Value Added by U.S. Production, "Without HDTV" Scenario, 1989 through 2003 86

LIST OF FIGURES

Figure | | Page
II-1. U.S. Color TV Manufacturing Industry, Key Indicators, 1980-1987 7
II-2. U.S. Producers of Color TV Receiver Sets, 1980-1987 9
II-3. U.S. Color TV Manufacturing Industry, Production Locations, 1980-1987 10
II-4. Color TV Manufacturing Product Mix by Screen Size, U.S. Production and Factory Production, Selected Years 13
III-1. Economic Contributions of U.S. Color TV Manufacturing, 1980, 1985, and 1987 20
III-2. Direct and Indirect Value Added and Employment Contributions of U.S. Color TV Manufacturing, by Industry, 1987 34
III-3. Induced Value Added and Employment Contributions of U.S. Color TV Manufacturing, by Industry, 1987 37
III-4. Percentage of Total Value Added and Employment Contribution of U.S. Color TV Manufacturing, Selected States, 1987 38
III-5. Percentage of Total Value Added and Employment Contribution of U.S. Color TV Manufacturing, 1987 41
III-6. Value Added and Employment Contributions of U.S. Color TV Manufacturing, Northeast Region, 1987 42
III-7. Value Added and Employment Contributions of U.S. Color TV Manufacturing, North Central Region, 1987 43
III-8. Value Added and Employment Contributions of Color TV Manufacturing, Southern Region, 1987 44
III-9. Value Added and Employment Contributions of Color TV Manufacturing, Western Region, 1987 45

LIST OF FIGURES

(Continued)

Figure		Page
IV-1.	U.S. Color TV Market with HDTV, Market Share by Screen Size, 1988 through 2003	52
IV-2.	U.S. Color TV Market Without HDTV, Market Share by Screen Size, 1988 through 2003	55
IV-3.	Forecast of Color TV and HDTV Unit Sales, Retail Value, U.S. Production, Retail Value of U.S. Production, and Value Added by U.S. Production, 2003	59
IV-4.	Potential Contribution of HDTV Receiver Set Manufacturing to the U.S. Economy, 2003	77

I. INTRODUCTION AND EXECUTIVE SUMMARY

The color television manufacturing industry in the United States is a vibrant and an increasingly productive and efficient contributor to the U.S. economy. Since 1980, its total contribution has grown 17.5 percent, from $15.4 billion to $18.1 billion. In 1980, the industry generated jobs, either directly or indirectly, for 200,000 workers. Today, the industry generates jobs for 240,000 workers, and Federal and state income tax revenues of $1.5 billion.

In 1987, U.S.-manufactured color televisions accounted for almost 70 percent of the total number of color televisions sold to final consumers and more than 70 percent of consumption expenditures on color televisions in the United States. Nineteen companies operated 21 production plants in more than a dozen states. Thirteen thousand production and administrative workers were employed. And 13.4 million sets worth $5.3 billion in retail value were manufactured. Currently (1988) 20 companies manufacture color televisions in the United States. Virtually all of the television sets 20 inches and larger in screen size that are sold in the United States are made in the United States. In addition, 50 percent of all the 13- to 19-inch color TVs that are sold in the United States are U.S. produced.

The development of high definition television (HDTV) will affect the nature of the U.S. color television manufacturing industry significantly. The new technology will have an effect on virtually all segments of the television industry: television program and software production, transmission systems, and reception and display equipment. HDTV will penetrate the marketplace rapidly with 10 percent of the U.S. households owning one HDTV set four years after introduction. This rate of penetration will be greater than the historical acceptance of color TV or VCRs. Twenty-five percent of U.S. households will own one HDTV set by the end of the 20th century. By 2003, 13.1 million HDTV sets will be produced and sold in the United States -- equal to the number of color televisions produced and sold in the United States in 1987. Ninety-two percent of these 13 million HDTV sets (12.1 million) will be manufactured in the United States.

HDTV will be a substitute product for current NTSC sets rather than a unique, entirely new product. Initially, HDTV's market share will be the 30-inch and larger screens. Increasingly, HDTV will dominate large screen sales (26-inch and larger) and eventually penetrate the 20- to 25-inch market -- achieving a 32.5 percent market share of all color TVs sold in 2003. The retail value of these sets will be more than 3.6 times the retail value of U.S. color television production in 1987 with at least 85 percent of the retail value expected to come from the U.S. TV pipeline.

Only the product mix, not the annual industry sales volume of color TVs, will be affected by the introduction of HDTV. And as HDTV's market share increases it has the potential to contribute $6.2 billion to the U.S. economy in 2003. Throughout the economy, the industry will generate jobs for more than 230,000 workers, about the same number of workers currently employed in the TV pipeline. HDTV will make additional contributions through substantial opportunities created in the design, development, installation, and operation of communications transmission equipment and delivery systems.

Industry Background

Television was first introduced in the United States with the initiation of regular service broadcasting in 1939. World War II interrupted commercial broadcasting and the commercialization of television. Soon after the war, television was reintroduced to the American household. In 1946, 6,900 sets were produced and made available to U.S. consumers. The factory value of this initial production run was just over $1 million. Although television was not an overnight success, as the technology improved and additional programs were broadcast, sales began to accelerate. The American public became captivated by "radio with pictures."

Color televisions became available to consumers in 1954. Again, sales were sluggish. Once transmission standards were determined and programs broadcast in color became more widely available, popular interest grew. By 1966, U.S. television manufacturers were producing and selling more than 5 million color televisions per year.

In the beginning, color television manufacturing required greater labor skills in assembly and testing. The tight labor market of the late 1960s initiated a movement of manufacturing to offshore locations. In the early 1970s, producers moved offshore to control production costs and remain competitive in the emerging global market place. The domestic manufacture and assembly of color televisions slowly re-emerged in the late 1970s.

Americans will soon be able to enjoy a major innovation in telecommunications — high definition TV (HDTV). HDTV is a configuration of sophisticated video and audio technologies that results in a picture of noticeably higher resolution and a quality of sound noticeably better than that available from the current transmission standard. At last count, more than 20 different HDTV systems are under development for consideration as the U.S. transmission standard.

The contributions of the color television manufacturing industry are both tangible and intangible. Either directly or indirectly, industry activity produces goods and services that add measurably to GNP, and it provides employment opportunities for hundreds of thousands of Americans. In addition, television contributes intangibly to the U.S. economy through its value as an education, communication, and entertainment medium. Televisions are found in almost every home, in most schools, and in many businesses.

Study Purpose

The Electronic Industries Association (EIA) asked Robert R. Nathan Associates, Inc. (RRNA) to analyze the U.S. color television manufacturing industry and estimate its contribution to the U.S. economy since 1980. In addition, EIA asked RRNA to analyze the potential impact of HDTV on the industry itself and the potential contribution of HDTV to the U.S. economy.

The first purpose of the RRNA study was to estimate the tangible contributions of color television manufacturing in the United States since 1980. Specifically, RRNA estimated the output of goods and services, the value added to GNP, employment, earnings, and the Federal and state income tax revenues generated from the domestic manufacture of color televisions. Results were expressed for major industry groups and for each state.

The second purpose of the RRNA study was to determine the likely future of HDTV and estimate its impact on the domestic color television manufacturing industry and its contribution to the U.S. economy. RRNA developed a forecast of HDTV production, sales, and impact through 2003.

Study Methods

RRNA used three methods to achieve these purposes. First, RRNA conducted mail and telephone surveys of industry experts and current manufacturers of color televisions in the United States to determine historical production volumes, factory value of production, prices, major television components, and, for each component, the percentage sourced overseas. The survey also solicited respondents' expectations for HDTV. Next, using the Multi-Regional Policy Impact Simulation (MRPIS) model, which was developed at the Social Welfare Research Institute (SWRI) at Boston College and includes a multi-regional input-output model, RRNA estimated the direct, indirect, and induced impacts on the economy (the contributions) of domestic color television manufacturing in total, by industry, and by state. Last, RRNA developed an econometric forecasting model for probable HDTV production and sales through 2003 and, based on the results of the MRPIS model, estimated HDTV's probable contribution to the U.S. economy in terms of value added and employment.

The findings of the study are presented in this report. Chapter II presents the results of the RRNA survey of color TV producers. Estimates of the contribution of the industry to the U.S. economy are presented in Chapter III. Chapter IV describes RRNA's forecast of the HDTV market and presents RRNA's estimate of HDTV's potential contribution to the U.S. economy.

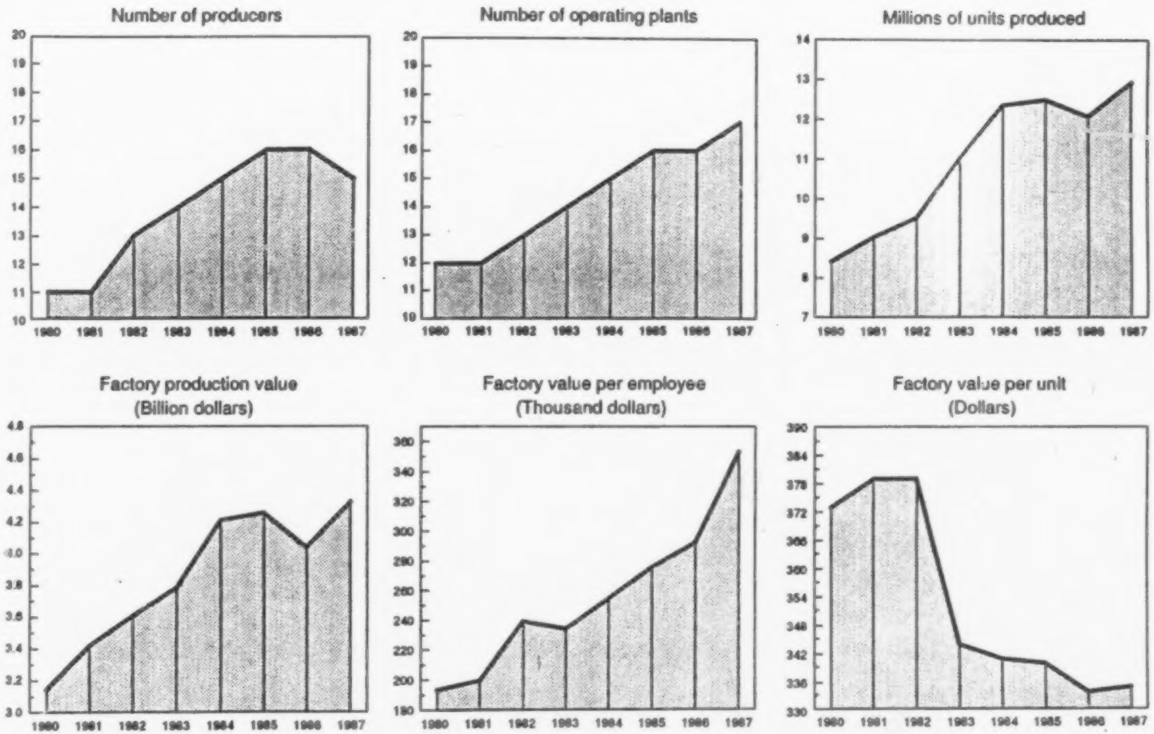
II. COLOR TV MANUFACTURING IN THE UNITED STATES

Color TV manufacturing is an expanding and increasingly productive U.S. industry. Since 1980, the number of manufacturers producing TVs in the United States has grown from 11 to 15 (see Figure II-1) and the number of production plants has increased from 12 to 17. At the beginning of the decade, U.S. plants produced 8.4 million sets with a factory value of $3.1 billion. In 1987, 12.9 million sets were manufactured in the United States with a value of $4.3 billion at the factory door. Productivity improvements with automation have resulted in a 100 percent increase in output per employee.

Survey Design

RRNA conducted a survey of production and employment by television manufacturers in the United States to document and measure the economic dimensions of the industry and to develop primary data required for estimating the contributions of the receiver manufacturing industry to the U.S. economy. Data were collected for 1980 through 1987 on the numbers of units and factory value of production, and on plant production and administrative employment. Information was also sought on the sourcing of major inputs to the manufacturing process -- picture tubes, electronic components, chassis, and kits -- and on distribution practices and changes in these practices over time. The survey included an introductory mailing, a questionnaire, and

Figure II-1. U.S. Color TV Manufacturing Industry, Key Indicators, 1980-1987



Source: RRNA.

telephone follow-up to maximize participation by U.S. manufacturers of direct view televisions.[1] Survey results for 1987 represent at least 75 percent of the manufacturers of TVs in that year and at least 94.5 percent of the total number of TVs produced in the United States.

Representation of TV Receiver Producers and Production Facilities

Color TV manufacturing has always been a fluid industry; the number of firms producing TV sets has expanded and contracted over time. The color TV industry of the 1980s has grown continuously throughout the decade.

Ten of the 15 companies that participated in the survey have manufactured color TVs in the United States throughout the 1980 to 1987 period -- Hitachi, Matsushita, Mitsubishi, Philips, Sanyo, Sony, Toshiba, Thomson/GE/RCA, Wells-Gardner, and Zenith (see Figure II-2). Two producers -- JVC and Sharp -- began domestic production in 1982, and one producer joined in each of the three following years -- Goldstar in 1983, Samsung in 1984, and NEC in 1985. GE purchased RCA in 1986 and completed the sale of its television manufacturing business to Thomson at the start of 1988.

In 1980, 12 production plants manufactured and/or assembled color TV sets; none was located in the Northeast region of the country (see Figure II-3). During the next seven years, eight plants opened, five by the new entrants and three as second plants for other producers -- Wells-Gardner (1981), Matsushita (1985), and Mitsubishi (1986). Three plants

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[1] Companies known to manufacture only projection TVs were excluded from the survey universe; survey results include projection TV production by the responding producers.

Figure II-2. U.S. Producers of Color TV Receiver Sets, 1980 - 1987

	Company	1980	1981	1982	1983	1984	1985	1986	1987
1	GE	X	X	X	X	X	X	X	X
2	Hitachi	X	X	X	X	X	X	X	X
3	Matsushita	X	X	X	X	X	X	X	X
4	Mitsubishi	X	X	X	X	X	X	X	X
5	Philips	X	X	X	X	X	X	X	X
6	RCA	X	X	X	X	X	X	X	(a)
7	Sanyo	X	X	X	X	X	X	X	X
8	Sony	X	X	X	X	X	X	X	X
9	Toshiba	X	X	X	X	X	X	X	X
10	Wells-Gardner	X	X	X	X	X	X	X	X
11	Zenith	X	X	X	X	X	X	X	X
12	JVC			X	X	X	X	X	X
13	Sharp			X	X	X	X	X	X
14	Goldstar				X	X	X	X	X
15	Samsung					X	X	X	X
16	NEC						X	X	X
	Total	11	11	13	14	15	16	16	15

a. RCA production facilities operated under GE ownership in 1987 and were then sold to Thomson at the start of 1988.

Source: RRNA.

Figure II-3. U.S. Color TV Manufacturing Industry, Production Locations, 1980 - 1987

	State	1980	1981	1982	1983	1984	1985	1986	1987
1	California	3	3	3	3	3	3	3	3
2	Illinois	3	3	2	2	2	2	2	2
3	Tennessee	2	2	3	3	3	3	3	3
4	Indiana	1	1	1	1	1	1	1	1
5	Arkansas	1	1	1	1	1	1	1	1
6	Missouri	1	1	1	1	1	1	1	1
7	Virginia	1	1	1	1	1	1		
8	New Jersey			1	1	2	2	2	2
9	Alabama				1	1	1	1	1
10	Georgia						1	1	2
11	Washington							1	1
	Total	12	12	13	14	15	16	16	17

Source: RRNA.

closed -- Zenith (1981), Wells-Gardner (1985, the same plant opened in 1981), and GE (1985, prior to its purchase of RCA).

Production Activity

U.S. production of color TV sets increased 53 percent during the period surveyed, from 8.4 million units in 1980 to more than 12.9 million in 1987. TVs made in the United States accounted, on average, for 73 percent of all the direct-view TVs produced for U.S. markets[2] and 75 percent of the total factory value of production (see Table II-1). Fluctuations in the U.S. share of production closely follow the entrance and departure of manufacturing firms and the opening and closing of production plants. U.S. shares of production and factory value peaked in 1982, in spite of the recession and high interest rates, and then declined to their earlier levels as a general shake-out of the industry occurred and as the U.S. production base faced increased foreign competition.

The differential between the U.S. share of factory value and share of units produced reflects a U.S. product mix that has become increasingly concentrated in the production of larger and more expensive sets. As illustrated in Figure II-4, the increasing percentage shares of the production of TV sets with screen sizes of 20 inches and larger started to accelerate in 1984, shortly after RCA's production of 26-inch picture tubes. By 1987, 20-inch and larger TVs accounted for about 65 percent of the TVs produced in the United States, a 100 percent increase in the share of all the sets produced for the U.S. market since 1980.

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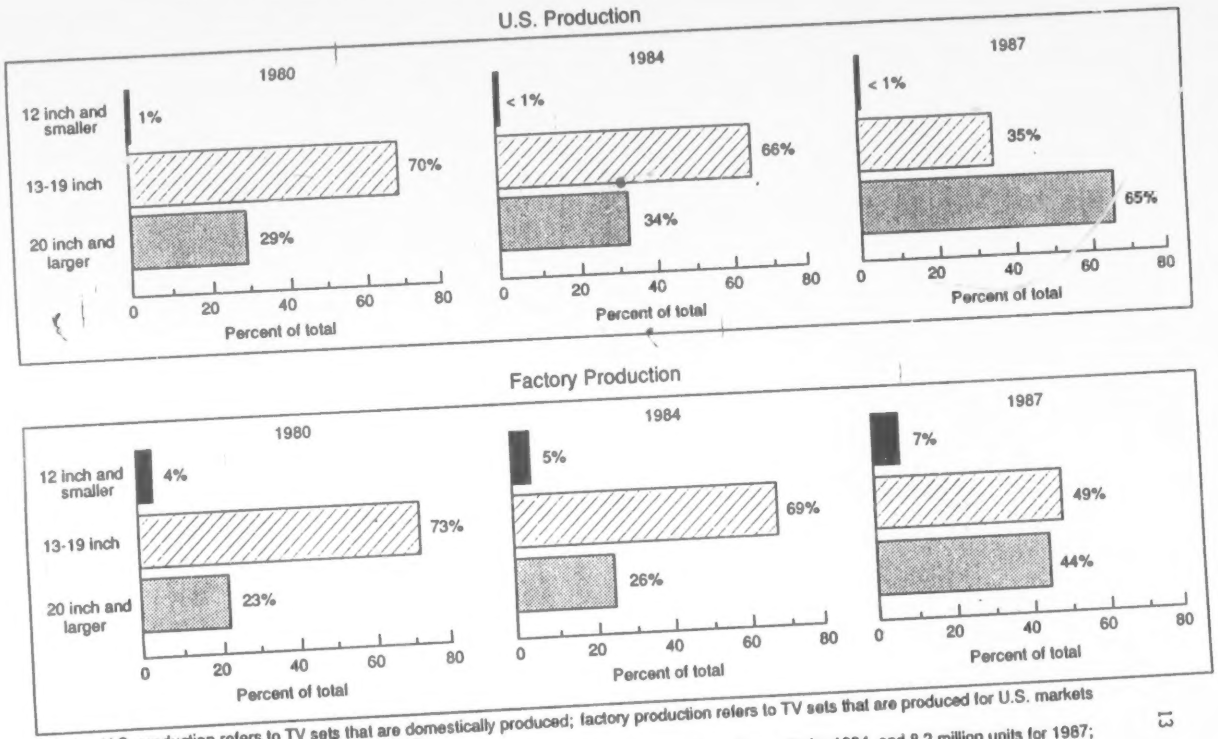
[2] TVs produced for U.S. markets are domestically produced and imported sets. A small percentage of the units produced in the United States are exported.

Table II-1. U.S. Production and Total Factory Production, Units Produced and Production Value, 1980 - 1987

Year	U.S. production Total (1)	 Index (1980=100) (2)	 Direct view (3)	 Index (1980=100) (4)	Factory production (5)	U.S. direct view production as a percent of factory production (6)=(3)/(5)x100
			millions			
Units produced						
1980	8.425	100.0	8.422	100.0	11.803	71.4
1981	9.027	107.1	9.015	107.0	12.423	72.6
1982	9.531	113.1	9.524	113.1	11.484	82.9
1983	11.007	130.6	10.989	130.5	14.034	78.3
1984	12.365	146.8	12.321	146.3	17.191	71.7
1985	12.502	148.4	12.456	147.9	16.905	73.7
1986	12.081	143.4	12.027	142.8	19.010	63.3
1987	12.924	153.4	12.854	152.6	19.847	64.8
			million dollars			
Production value						
1980	3,144	100.0	3,136	100.0	4,210	74.5
1981	3,421	108.8	3,392	108.2	4,349	78.0
1982	3,608	114.8	3,591	114.5	4,253	84.4
1983	3,788	120.5	3,758	119.8	5,002	75.1
1984	4,211	133.9	4,139	132.0	5,538	74.7
1985	4,256	135.4	4,187	133.5	5,562	75.3
1986	4,040	128.5	3,967	126.5	6,025	65.8
1987	4,327	137.6	4,245	135.4	6,271	67.7

Sources: RRNA for U.S. production and EIA Electronic Market Data Book, 1988, Table 1-4 for factory production and Table 1-5 for production value.

Figure II-4. Color TV Manufacturing Product Mix by Screen Size, U.S. Production and Factory Production, Selected Years



Note: U.S. production refers to TV sets that are domestically produced; factory production refers to TV sets that are produced for U.S. markets which are either domestically produced or imported.

Source: RRNA for U.S. production market shares, based on 2.2 million units for 1980, 5.0 million units for 1984, and 8.2 million units for 1987; EIA for factory production, Color Television Activity Report MS-122-M, year end cumulative.

The changing product mix and emerging distinction between domestic production and imports is reflected in the regional distributions of U.S. production activity presented in Table II-2. In 1980, production plants in the North Central and South census regions accounted for almost 90 percent of all U.S. production. More than 50 percent of the total was produced in the Midwestern states. The shares of factory value of production in the North Central and West census regions were marginally greater than their respective shares of units produced, indicative of the production of higher priced units in these regions than in the South, where the opposite relationship prevailed. By 1987, with the new plants operating in the South and Northeast, the North Central region's share of units had declined to almost 40 percent of the total; the share of units produced in the West had also declined, but to a much lesser extent. TV set production in the Northeast region has been concentrated on manufacture of the less expensive and smaller color TVs (13-inch to 19-inch screen sizes). The relationships in the other regions are the same as they were in 1980, only the differentials are greater -- plants in the North Central and West regions have increased their production of the larger and more expensive (20-inch and larger) TVs.

Plant Employment and Productivity

Increases in production and factory value of TVs in the last seven years have been achieved with a slowly contracting work force. These trends over the survey period are demonstrated with the data summarized in Table II-3. Employment in plant production and administration has generally varied between 15,000 and 16,000. Employment peaked in 1981, with the start-up of two new plants, and then returned to its prior level in the industry shake-out caused by the 1982 recession, high interest rates, and increased

Table II-2. U.S. Color TV Manufacturing Industry, Units Produced and Production Value, by Census Regions, 1980 - 1987

	1980	1981	1982	1983	1984	1985	1986	1987
				millions				
Units produced								
Northeast (a)					0.123	0.405	0.599	0.680
North Central	4.390	5.126	4.895	5.471	5.776	5.486	4.852	5.279
South	3.009	2.823	3.594	4.445	5.122	5.211	5.115	5.546
West	1.026	1.079	1.042	1.092	1.343	1.400	1.516	1.419
Total	8.425	9.027	9.531	11.007	12.365	12.502	12.081	12.924
				percent				
Distribution of units produced								
Northeast (a)	0.0	0.0	0.0	0.0	1.0	3.2	5.0	5.3
North Central	52.1	56.8	51.4	49.7	46.7	43.9	40.2	40.8
South	35.7	31.3	37.7	40.4	41.4	41.7	42.3	42.9
West	12.2	12.0	10.9	9.9	10.9	11.2	12.5	11.0
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
				billion dollars				
Production value								
Northeast (a)					0.000	0.085	0.117	0.140
North Central	1.727	1.992	1.936	1.958	2.100	2.097	1.830	1.948
South	1.014	0.966	1.236	1.425	1.586	1.583	1.527	1.672
West	0.403	0.463	0.435	0.405	0.482	0.492	0.565	0.567
Total	3.144	3.421	3.608	3.788	4.169	4.256	4.040	4.327
				percent				
Distribution of production value								
Northeast (a)	0.0	0.0	0.0	0.0	0.0	2.0	2.9	3.2
North Central	54.9	58.2	53.7	51.7	50.4	49.3	45.3	45.0
South	32.3	28.2	34.3	37.6	38.0	37.2	37.8	38.6
West	12.8	13.5	12.1	10.7	11.6	11.6	14.0	13.1
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Note: Totals may not sum due to rounding.

a. No production in Northeast in 1980 and 1981; Northeast production included with North Central for 1982 and 1983 to preserve confidentiality of respondents.

Source: RRNA.

Table II-3. U.S. Color TV Manufacturing Industry, Summary of Production, Factory Value, and Plant Employment (Production and Administrative Workers), 1980 - 1987

Year	Production		Plant employment	Factory value per unit (dollars)	Units per employee	Factory value per employee (dollars)
	Units (millions)	Factory value (billions)				
	(1)	(2)	(3)	(4)=(2)/(1)	(5)=(1)/(3)	(6)=(2)/(3)
1980	8.425	3.144	16,259	373	518	193,370
1981	9.027	3.421	17,136	379	527	199,638
1982	9.531	3.608	15,080	379	632	239,257
1983	11.0[illegible]	3.787	16,172	344	681	234,170
1984	12.365	4.211	16,533	341	748	254,703
1985	12.502	4.256	15,444	340	810	275,576
1986	12.081	4.040	13,832	334	873	292,076
1987	12.924	4.327	12,267	335	1,054	352,735

Source: RRNA.

foreign competition. Employment declines in the last several years are due to plant closings, including that of a major production plant in 1985.

The U.S. color TV manufacturing industry has achieved substantial increases in productivity, continuing long-term industry-wide trends dating to the 1960s that have been driven by an increasingly automated production process. Over the eight-year period, the number of units produced per employee increased 103 percent, and factory value of production per employee increased 82 percent. The increased productivity and efficiency characteristic of the industry has resulted in an 11 percent reduction in the average factory value of a TV set produced in the United States. U.S. producers are sending more and more large-screen TV sets to the market at lower costs and lower prices.

The regional distributions of plant employment presented in Table II-4 help to illustrate the dynamics of the industry. The impact of the more recently opened production plants can be seen by comparing the regional employment shares with the shares of production and factory value (Table II-2) across the years. In 1980, production plants in the North Central region, a traditional location for TV manufacturing, accounted for a share of plant employment smaller than their share of production, while the opposite situation prevailed in the South and in the West. By 1987, the relationship in the South changed from the situation in 1980. The employment-production relationship for the producers and plants in the South has reversed; now their share of employment is smaller than their share of production, reflecting a more efficient manufacturing process. In the North Central and West regions, the relationships that existed in 1980 prevail, and those relationships are also characteristic of the new producers operating plants in the Northeast.

Table II-4. U.S. Color TV Manufacturing Industry, Plant Employment, by Census Regions, 1980 - 1987

	1980	1981	1982	1983	1984	1985	1986	1987
	thousands							
Persons employed								
Northeast (a)	0.0	0.0	0.0	0.0	0.2	0.3	0.3	0.4
North Central	7.5	8.3	6.1	6.9	7.0	6.1	5.9	5.1
South	6.4	6.2	6.5	6.9	6.8	6.6	4.8	4.2
West	2.3	2.6	2.4	2.4	2.5	2.4	2.8	2.6
Total	16.3	17.1	15.1	16.2	16.5	15.4	13.8	12.3
	percent							
Employment distribution								
Northeast (a)	0.0	0.0	0.0	0.0	1.5	1.7	2.5	2.9
North Central	46.4	48.5	40.7	42.8	42.6	39.6	43.0	41.2
South	39.4	36.1	43.4	42.4	40.8	43.0	34.4	34.5
West	14.2	15.4	15.9	14.8	15.1	15.6	20.2	21.3
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Note: Totals may not sum due to rounding.

a. No production in Northeast in 1980 and 1981; Northeast production included in North Central for 1982 and 1983 to preserve confidentiality of respondents.

Source: RRNA.

III. CONTRIBUTIONS OF COLOR TV MANUFACTURING TO THE U.S. ECONOMY

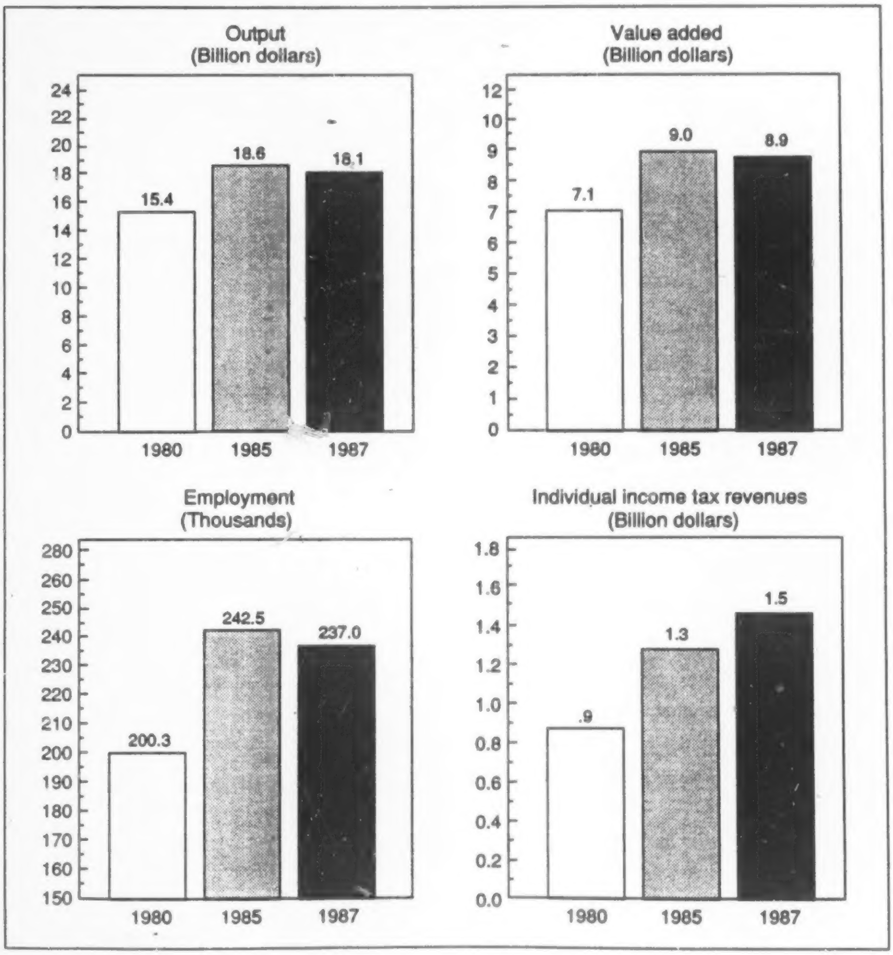
The 1980s have been growth years for color TV manufacturing in the United States and for the industry's contributions to the economy. Since 1980, the total impact of the industry, as measured in goods and services, has increased 17.5 percent, from $15.4 billion to $18.1 billion, contributing $8.9 billion to GNP in 1987 (see Figure III-1). At the beginning of the decade, the color TV manufacturing industry created employment for 200,000 workers; today, the industry is responsible for the employment of nearly 240,000 workers throughout the economy, who pay $1.5 billion in Federal and state income taxes.

Estimating the Economic Impacts of TV Manufacturing

The economic contributions of color TV manufacturing to the U.S. economy were estimated using input-output (I-O) analysis. I-O models operate under the assumption that there is a relatively stable pattern of flows of goods and services among the basic elements of the economy. I-O analysis helps estimate the economic dimensions of the flows of products and services among the sectors of the economy.

I-O modeling allows the estimation of the total impact of the economic activity within a region generated by a specific economic activity by determining the marginal changes throughout the economy associated with the

Figure III-1. Economic Contributions of U.S. Color TV Manufacturing, 1980, 1985, and 1987



Source: RRNA.

functioning of the activity under study. The total impact is the sum of three components: a direct effect, an indirect effect, and an induced effect. The direct effect is the value of production by the economic activity of interest -- in this case, the manufacture of color TVs. The manufacture of receiver sets is the key station in the TV pipeline and the "root source" of the pipeline's contributions to the economy. At other points in the pipeline -- raw materials, component parts and subassembly manufacturing, distribution, and final sale -- materials and services from other industries are produced and consumed and labor is employed to produce and market television sets. The value of these contributions is the indirect effect of the primary, direct effect. Workers employed in generating the direct and indirect contributions earn wages and salaries that are expended, in part, on personal consumption. Personal consumption generates additional economic activity, which is an induced effect and the third component of economic contribution.

RRNA used the Multi-Regional Policy Impact Simulation (MRPIS) model developed at the Social Welfare Research Institute, Boston College, to estimate the economic contributions of color TV manufacturing. MRPIS was developed to measure and analyze the differential regional impacts of economic activity. It incorporates separate input-output structures for each state in the nation. In this application, MRPIS estimates are driven by final demand for color TVs consisting of personal consumption, government expenditures, and net exports; changes in inventories are taken into account in estimating final demand.

The MRPIS model was used to estimate the economic contributions of color TV manufacturing in 1985. Estimates of selected indicators of economic impact were also developed for 1980 and 1987 in order to gauge the changes in the impacts of the industry on the economy during the 1980s. National estimates of output, value added, employment, and (individual income) tax revenues were produced as were state-by-state estimates of value added and employment. The results of these analyses are reported in the remainder of this chapter under three broad themes -- growth and development, industry composition, and location of the economic contributions of TV manufacturing in the United States.

Growth and Development in Output, Value Added, and Employment

The growth in the color TV receiver set manufacturing industry reported in Chapter II is reflected in three broad indicators of the contribution of the industry to the economy: output, value added, and employment.[3] Output generated by the manufacturing, distribution, and sale of color TVs in the United States increased 17.5 percent from 1980 to 1987. The number of workers employed in the economy because of color TV manufacturing increased by about the same percentage (18.4 percent) as output. The color TV manufacturing industry's contribution to GNP (value added) grew by 24 percent since the beginning of the decade, an increase greater than the growth in output and employment.[4]

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[3] Output is the amount of goods produced and shipped and services provided, including intermediate products and services employed in the production of final products and services. Value added is the difference between the value of shipments in producers' prices and the cost of goods sold. Employment includes production and supervisory workers and those employed in administrative and auxiliary units.

[4] These are conservative estimates of the economic contributions of color TV manufacturing. The MRPIS model does not account for the impact of investment on the economy except to the extent that returns to investments are received as unearned income by workers employed in the TV pipeline or in the production of goods and services purchased by workers in the pipeline with their disposable income. The same is true for other input-output models that could be used for this research.

Economic Contributions of TV Manufacturing by Industry Group, 1980 to 1987

The economic contributions of U.S. TV manufacturing for the economy as a whole and by broad industry groups are summarized in Table III-1. Output, value added, and employment impacts are presented with more industry detail in Appendix A, Table A-1. In the aggregate and within the broad groupings, most of the growth in economic contribution occurred between 1980 and 1985; output, value added, and employment were about the same in 1987 as they were in 1985.

Major growth in the 1980s took place early in the decade.[5] By the beginning of 1986 a major production plant had closed, but by 1987 the other producers had expanded their market shares, as the demand for television sets remained strong. The stability between 1985 and 1987 also reflects continuing productivity improvements -- not only in the TV manufacturing industry, but also in other industrial sectors that are affected by or involved in the manufacturing of TVs.

The numbers of TV sets produced in the United States in 1985 and 1987 were the same, 13.4 million[6]; the difference in the value of production (value of shipments in producers' prices) between these two years is a reflection of the achievement of lower costs with productivity improvements and, in turn, lower prices for TV sets in retail stores. TV manufacturing is an extremely competitive industry, and manufacturers in the United States have worked hard to expand production and decrease costs and prices.

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[5] 5. See Chapter II, pp. 8-11 for a discussion of industry structure and membership.

[6] 6. These production volumes are estimated on the basis of the survey results reported in Chapter II.

Table III-1. Summary of Output, Value Added, and Employment, by Industry Group, 1980, 1985, and 1987

Industry group	1980	1985	1987
	billion dollars		
Output			
TV industries	4.590	5.594	5.308
Basic industries	.602	.768	.767
Other manufacturing industries	3.218	4.008	3.973
Trade	2.967	3.094	2.959
Services	2.765	3.537	3.521
Transportation, communications, utilities, and other	1.238	1.559	1.541
Total	15.380	18.560	18.069
	billion dollars		
Value added			
TV industries	1.538	2.324	2.244
Basic industries	.320	.406	.405
Other manufacturing industries	1.141	1.412	1.396
Trade	1.607	1.671	1.595
Services	1.751	2.241	2.230
Transportation, communications, utilities, and other	.779	.995	.984
Total	7.136	9.048	8.853
	thousands		
Employment			
TV industries	37.5	45.9	45.1
Basic industries	6.8	8.7	8.7
Other manufacturing industries	26.3	32.7	32.4
Trade	71.9	79.9	76.1
Services	42.0	54.0	53.6
Transportation, communications, utilities, and other	15.9	21.3	21.2
Total	200.3	242.5	237.0

Note: Items may not sum to totals due to rounding.
Source: Table A-1.

Industry Developments in the 1980s

The percentage change between 1980 and 1987 in output, value added, and employment by detailed industry groups is set out in Table III-2. The general pattern across the set of industries is one of consistent growth in terms of the three indicators. There are a few extremely relevant and important exceptions. The contributions of the electronic components and parts industry and the wholesale trade industry have declined; the percentage changes in these industries' contributions to TV production and distribution have been consistent across the three indicators. The other exception is the TV receiver set manufacturing industry. The receiver set industry's portion of economic impact has grown, but the growth has not been the same with regard to each of the indicators.

The contributions of the electronic components and parts industry to the U.S. economy that are attributable to color TV manufacturing declined about 10 percent during the 1980 to 1987 period. The sourcing of these and other materials used in manufacturing TVs is in part a function of foreign exchange rates as manufacturers seek the lowest cost inputs used in the manufacturing process. The decline in the TV-related economic contributions in this industry has been fueled by the development and market introduction of large screen (26-inch and larger) TVs in 1984.

The electronic components and parts contained in a TV set represent a relatively small portion of the cost of a television set, about 14 percent of the factory cost and 7.5 percent of the retail price. The picture tube and (wooden) cabinet together make up about 60.5 percent of the factory costs (about

Table III-2. Contributions of U.S. Color TV Manufacturing, Percent Change by Industry, 1980 - 1987

Industry	Percent change, 1980 - 1987		
	Output	Value added	Employment
TV industries			
TV receiver sets	15.3	57.5	-21.3
Picture tubes	12.3	12.5	12.1
Electronic components and parts	(10.2)	(10.1)	(9.1)
Furniture cabinetry	39.5	38.6	41.3
Subtotal	15.6	45.8	20.3
Basic industries			
Raw materials (a)	28.8	27.6	31.3
Construction	24.5	24.2	25.5
Subtotal	27.5	26.5	28.5
Other manufacturing industries			
Other durable	20.7	20.1	20.6
Non-durable	25.3	24.2	25.8
Subtotal	23.5	22.3	23.3
Trade			
Wholesale	(19.1)	(19.5)	(19.1)
Retail	17.5	17.1	16.7
Subtotal	(0.3)	(0.8)	5.9
Services			
Advertising	12.9	12.9	14.6
Finance, insurance, and real estate	28.8	28.8	28.5
Other services	30.3	30.2	31.9
Subtotal	27.4	27.4	27.5
Transportation, communications, utilities, and other			
Transportation	18.6	18.3	18.2
Communications and utilities	21.7	20.9	21.1
Other	39.5	41.6	53.1
Subtotal	24.4	26.4	33.3
Total	17.5	24.1	18.4

a. Includes agriculture, forestry, fishing, and mining.

Source: Calculated from Table A-1.

as a result of productivity improvements. Output, or the value of production shipped to dealers, also increased but less so, reflecting the same developments — internalization of the wholesaling function but reductions in production costs and, in turn, producers' prices.

The twin effects of changes in wholesaling practices and enhanced production economies on the industry's direct contributions to the economy are illustrated by the figures set out in Table III-3. Estimates of the value of shipments (net of foreign content) and value added in set manufacturing from the MRPIS model for 1980, 1985, and 1987 are supplemented by information from the 1982 Census of Manufactures conducted by the U.S. Department of Commerce, Bureau of the Census. Over the time span represented by the four sets of figures, value added as a percent of value of shipments has increased 33 percent, from just less than 30 percent in the two earlier years to just over 40 percent in the two most recent years. The noticeable improvement in the efficiency of the industry's direct contributions to the U.S. economy is the result of productivity improvements, changes in distribution practices, and domestic concentration in the manufacturing of large screen television sets.

Economic Impact of TV Manufacturing by Source and Industry: 1987

Color TV manufacturing in the United States affects every sector of the economy. Table III-4 sets out the same measures of economic impact for the same broadly defined industry groups used in Table III-1; in this presentation each industry group's contribution is expressed as a percentage of the total for each year.

32.2 percent of retail price).[7] Domestic sourcing of these inputs to the manufacturing process has also decreased during the same 1980 to 1987 period but to a much lesser extent than for the electronic components. The development and marketing of large screen sets has countered foreign sourcing trends for picture tubes and cabinets; these larger sets are typically manufactured in the United States because of their large size and the transportation costs associated with foreign sourcing of inputs.

The economic contributions from the wholesaling, or distribution, of color TVs also declined from 1980 to 1987. The decline in wholesale trade's contribution to the U.S. economy from the distribution of U.S.-made TV sets reflects the increasing internalization of this function within the TV receiver set manufacturing industry. As the TV manufacturing industry concentrated on building productive capacity and production economies, it also moved towards bringing the wholesaling of production in-house. Internalization of the wholesaling function has allowed the manufacturer to capture (and thus control) the wholesalers' margins, a development consistent with the price competitiveness of the TV consumer product industry.

The differential growth in the output, value added, and employment of the receiver set manufacturing industry from 1980 to 1987 reflects, for the most part, the change in distribution practices. Of the three indicators of economic contribution, value added attributable to the receiver set industry increased the most, nearly 58 percent. Value added should be the most responsive to the industry's change in distribution practices as manufacturers absorb wholesalers' margins. The increase in employment also reflects self-wholesaling, as marketing personnel were added to manufacturers' payrolls; employment growth was also moderated by declining production employment

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[7] The picture tube alone is about 50 percent of the factory cost of a TV set.

Table III-3. TV Receiver Set Manufacturing Industry, Value of Shipments and Value Added, Selected Years

Year	Value of shipments (a)	Value added	Value added as a percent of value of shipments
	---- billion dollars ----		---- percent ----
1980	3.685	1.103	29.9
1982	3.771 (b)	1.124	29.8
1985	4.580	1.842	40.2
1987	4.248	1.738	40.9

a. Includes only the value of domestic content

b. The domestic content of value of shipments is estimated to be 95.7 percent of the $3.492 billion reported in the 1982 Census of Manufactures.

Source: RRNA for 1980, 1985, 1987 figures; Census of Manufactures, U.S. Department of Commerce, Bureau of the Census for 1982 figures.

Table III-4. Summary of Output, Value Added, and Employment, Percent Distribution by Industry Group, 1980, 1985, and 1987

Industry group	1980	1985	1987
Output			
TV industries	29.8	30.1	29.4
Basic industries	3.9	4.1	4.2
Other manufacturing industries	20.9	21.6	22.0
Trade	19.3	16.7	16.4
Services	18.0	19.1	19.5
Transportation, communications, utilities, and other	8.1	8.4	8.5
Total	100.0	100.0	100.0
Value added			
TV industries	21.6	25.7	25.3
Basic industries	4.5	4.5	4.6
Other manufacturing industries	16.0	15.6	15.8
Trade	22.5	18.4	18.0
Services	24.5	24.8	25.2
Transportation, communications, utilities, and other	10.9	11.0	11.1
Total	100.0	100.0	100.0
Employment			
TV industries	18.7	18.9	19.0
Basic industries	3.4	3.6	3.7
Other manufacturing industries	13.1	13.5	13.7
Trade	35.9	32.9	32.1
Services	21.0	22.3	22.6
Transportation, communications, utilities, and other	7.9	8.8	8.9
Total	100.0	100.0	100.0

Source: Calculated from Table A-1.

The percentage shares by industry grouping for the indicators shown in Table III-4 have been fairly consistent over the period, with 30 percent of the output and 19 percent of the employment generated by TV manufacturing in the United States attributable to TV-related manufacturing industries (receiver set manufacturing, picture tubes, electronic components and parts, and cabinets); the portion of value added by TV-related industries has increased from 22 percent to 25 percent. The remainder (70 percent of output, 81 percent of employment, and 75 percent of value added) is divided among the basic raw materials and construction industries, other durable and non-durable manufacturing, wholesale and retail trade, services, and transportation, communications, utilities, and other industries.

The total contribution of TV manufacturing in the United States is the sum of an initial (direct and indirect) component and an induced component. The direct and indirect effects are associated with the activities comprised in the TV pipeline. Induced effects reflect a different set of activities -- those involved in producing the products and services purchased and consumed by workers employed in the TV production and distribution chain.

Valued Added and Employment in the Color TV Pipeline, 1987

Two industries, the TV receiver set manufacturing industry and retail trade, account for almost half of the TV pipeline's contributions to GNP and the employment created by the production and distribution of U.S.-made televisions. The direct and indirect contributions of TV manufacturing by the industries comprised in the TV pipeline are arrayed in Table III-5. The TV industries (receiver sets, picture tubes, electronic components and parts, and furniture cabinetry) and the trade group (wholesale and retail) together are responsible for about 65 percent of value added and nearly 70 percent of the

Table III-5. Direct and Indirect Value Added and Employment Contribution of U.S. Color TV Manufacturing, by Industry, 1987

	Value added		Employment	
Industry	Amount (billion dollars)	Percent distribution	Amount (thousands)	Percent distribution
TV industries				
TV receivers	1.738	34.6	28.0	21.3
Picture tubes	.336	6.7	10.1	7.7
Electronic components and parts	.033	0.7	1.0	0.8
Furniture cabinetry	.118	2.4	5.3	4.0
Subtotal	2.225	44.3	44.4	33.7
Basic industries				
Raw materials	.083	1.7	1.1	0.8
Construction	.042	0.8	1.4	1.1
Subtotal	.125	2.5	2.5	1.9
Other manufacturing industries				
Other durable	.389	7.8	9.3	7.1
Non-durable	.308	6.1	6.8	5.2
Subtotal	.697	13.9	16.1	12.2
Trade				
Wholesale	.455	9.1	12.7	9.7
Retail	.557	11.1	33.6	25.5
Subtotal	1.012	20.2	46.4	35.2
Services				
Advertising	.149	3.0	6.5	4.9
Finance, insurance, and real estate	.263	5.2	2.6	2.0
Other services	.179	3.6	7.2	5.4
Subtotal	.591	11.8	16.2	12.3
Transportation, communications, utilities, and other				
Transportation	.152	3.0	3.6	2.7
Communications	.068	1.4	1.0	0.8
Utilities	.067	1.3	0.7	0.5
Other	.079	1.6	0.7	0.6
Subtotal	.367	7.3	6.0	4.6
Total	5.017	100.0	131.7	100.0

Note: Items may not sum to totals due to rounding.
Source: RRNA.

employment contributions of TV manufacturing. Two other industry groups -- other manufacturing and services -- are responsible for 25 percent of the pipeline's impacts; the remaining 10 percent of value added and 5 percent of employment is contributed by the basic industry group and by the transportation, communications, and utilities services used in producing and distributing TVs.

The broad industry groupings mask the identity of the many narrowly defined economic activities that contribute to the impact of TV manufacturing on the U.S. economy. Some of the more detailed industries, in addition to the TV industries, are identified in Figure III-2. Those industries are responsible for nearly 50 percent of the value added generated and almost 60 percent of the employment opportunities created in the economy by the U.S. TV pipeline.[8] Many more industries account for the remainder.

Induced Economic Contributions of Color TV Manufacturing (Value Added and Employment), 1987

U.S. wage and salary workers employed because of the TV pipeline spend their earnings on a wide variety of goods and services. Almost 60 percent of the induced value added and more than 60 percent of the induced employment in the economy attributable to the manufacturing of TVs accrue from the trade and service industry groups. The induced contributions to GNP and to employment created in the United States from the U.S. TV production and distribution chain are set out in Table III-6. Retail trade and other services (primarily housing and health-related services) compose

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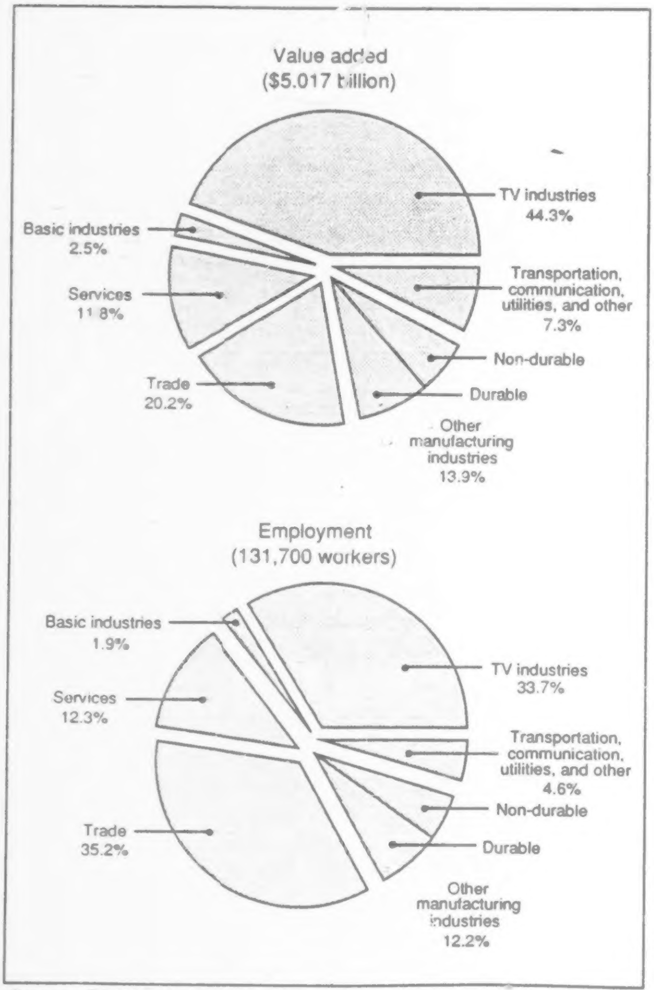
[8] These figures do not include the contribution attributable to the TV-related industries.

Figure III-2. Direct and Indirect Value Added and Employment Contributions of U.S. Color TV Manufacturing, by Industry, 1987



TV industries:

Receiver sets
Picture tubes
Electronic components and parts
Furniture cabinetry

Basic industries:

Coal
Crude petroleum
Natural gas
Construction

Non-durable manufacturing:

Logging and lumber
Wood products
Paper products
Paperboard containers
Newspaper and other printing
Industrial chemicals
Other chemicals
Plastics and synthetics
Petroleum refining
Rubber and plastics

Durable manufacturing:

Glass and related products
Stone and clay products
Iron and steel forging
Metal containers
Screw machine products
Other non-electrical equipment
Office and computing equipment
Electrical equipment
Electric lighting

Trade:

Wholesale trade
Eating and drinking places
General mechandise stores

Services:

Banking and credit agencies
Insurance
Real estate
Personal and repair services
Advertising and other services
Professional services

Transportation, communications, utilities, and other:

Railroads
Motor freight
Air transportation
Communications
Electric utilities
Government agencies

Source: RRNA.

Table III-6. Induced Value Added and Employment Contribution of U.S. Color TV Manufacturing, by Industry, 1987

Industry	Value added		Employment	
	Amount (billion dollars)	Percent distribution	Amount (thousands)	Percent distribution
Basic industries				
Raw materials	.200	5.2	3.5	3.3
Construction	.080	2.1	2.7	2.5
Subtotal	.280	7.3	6.2	5.9
Manufacturing industries				
Durables	.261	6.8	6.2	5.9
Non-durables	.456	11.9	10.7	10.1
Subtotal	.717	18.7	16.9	16.1
Trade				
Wholesale	.177	4.6	4.8	4.6
Retail	.406	10.6	24.9	23.6
Subtotal	.583	15.2	29.7	28.2
Services				
Advertising	.086	2.2	3.7	3.5
Finance, insurance, and real estate	.929	24.2	8.6	8.2
Other services	.624	16.3	25.1	23.8
Subtotal	1.639	42.7	37.4	35.5
Transportation, communications, utilities, and other				
Transportation	.112	2.9	2.7	2.5
Communications	.113	2.9	1.7	1.6
Utilities	.140	3.6	1.5	1.4
Other	.253	6.6	9.3	8.8
Subtotal	.618	16.1	15.2	14.4
Total	3.837	100.0	105.4	100.0

Note: Items may not sum to totals due to rounding.
Source: RRNA.

about 27 percent of induced GNP and almost 50 percent of induced employment.

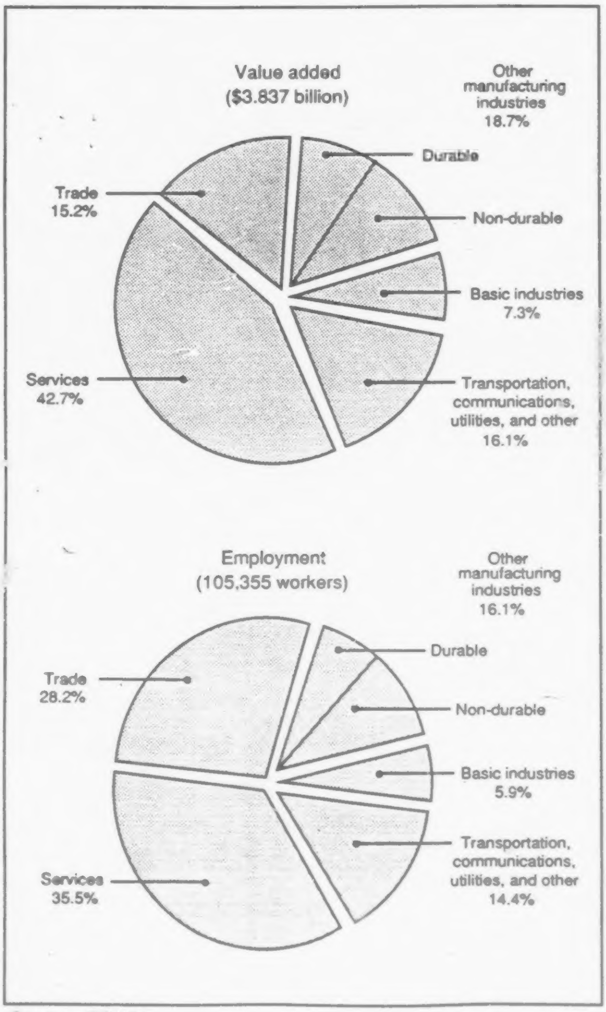
The industrial composition of these consumption-related impacts would be the same, generally, if the consumer expenditures were by workers employed in the U.S. automobile pipeline, for example, or in any other interrelated production- or service-oriented set of economic activities. The figures set out in Table III-6 reflect the typical mix of products and services in the "market basket" purchased by U.S. workers. Some of the detailed industries involved in producing the goods and services purchased are identified in Figure III-3. These industries account for 86 percent of the GNP and 84 percent of the employment induced in the economy because of the manufacturing and distribution of U.S.-made TVs.

Economic Impact of TV Manufacturing, by Location: 1987

The economies of every state in the nation are affected by the manufacture and sale of TV sets. More than one-third of the economic contributions of TV manufacturing accrue in three states -- Indiana, Tennessee, and California -- and about one-half accrue in another 12 states. The top 17 states are responsible for about 85 percent of the value added and employment impacts of TV manufacturing; they are identified in Figure III-4. These largest impact states are either states with TV manufacturing or TV-related industries, or are the states with the largest populations (and, therefore, the largest amount of sales of televisions), or are the location of both TV (or TV-related) production and large populations.

A summary of the impact of TV manufacturing and distribution by location is arrayed in Table III-7; state-by-state detail is set out in Table A-2. TV

Figure III-3. Induced Value Added and Employment Contributions of U.S. Color TV Manufacturing, by Industry, 1987



Basic industries:
Livestock
Cotton, grain, and tobacco
Fruit, nuts, and other crops
Coal
Crude petroleum
Natural gas
Construction

Non-durable manufacturing:
Meat products
Dairy products
Canned and frozen foods
Grain mill products
Bakery products
Beverages
Fabric, yarn, and thread mill products
Apparel
Paper products
Newspaper and other printing
Industrial chemicals
Pharmaceuticals
Petroleum refining
Rubber and plastics

Durable manufacturing:
Iron and steel forging
Metal containers
Motor vehicles and parts
Scientific and photographic equipment
Other manufactured products

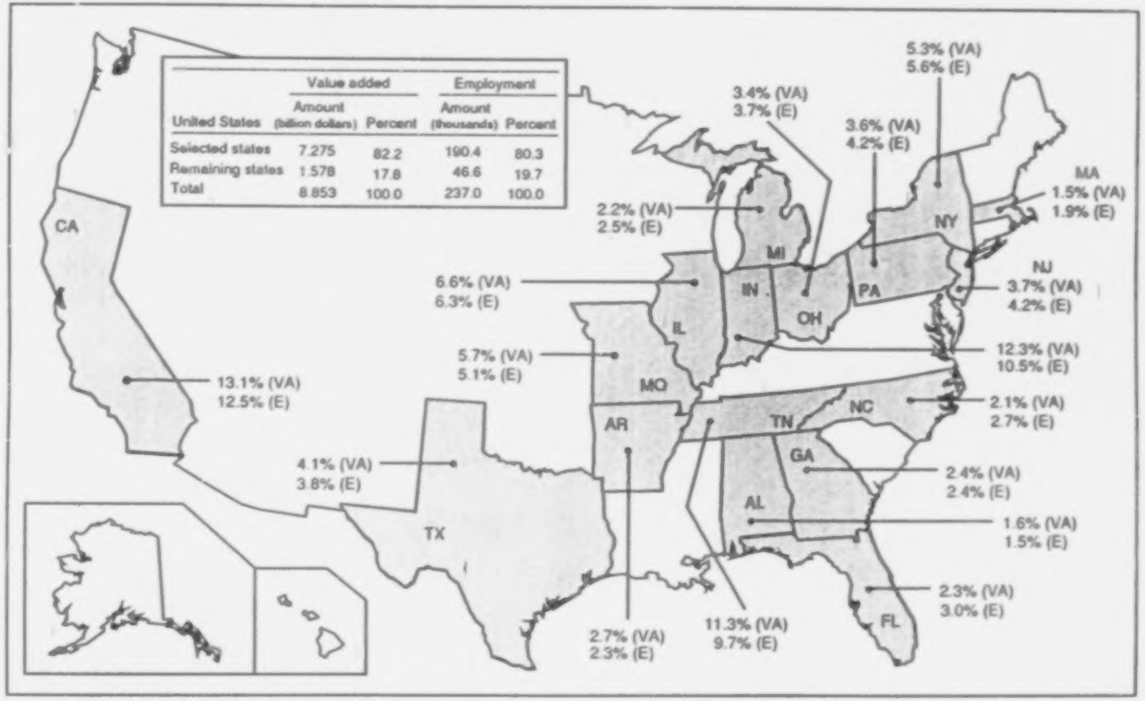
Trade:
Wholesale trade
Eating and drinking places
General mechandise stores
Food, drugs, and liquor stores
Automobile dealers and gas stations
Other retail stores

Services:
Banking and credit agencies
Insurance
Real estate
Hotels
Personal and repair services
Advertising and other services
Professional services
Auto rental and repair
Medical services
Educational and social services

Transportation, communication, utilities, and other:
Railroads
Motor freight
Air transportation
Communications
Radio and TV broadcasting
Electric utilities
Gas utilities
Water and sanitary service
Government agencies

Source: RRNA.

Figure III-4. Percentage of Total Value Added and Employment Contribution of U.S. Color TV Manufacturing, Selected States, 1987



	Value added		Employment	
United States	Amount (billion dollars)	Percent	Amount (thousands)	Percent
Selected states	7.275	82.2	190.4	80.3
Remaining states	1.578	17.8	46.6	19.7
Total	8.853	100.0	237.0	100.0

CA
13.1% (VA)
12.5% (E)
TX
4.1% (VA)
3.8% (E)
AR
2.7% (VA)
2.3% (E)
MO
5.7% (VA)
5.1% (E)
IL
6.6% (VA)
6.3% (E)
MI
2.2% (VA)
2.5% (E)
IN
OH
3.4% (VA)
3.7% (E)
PA
3.6% (VA)
4.2% (E)
NY
5.3% (VA)
5.6% (E)
MA
1.5% (VA)
1.9% (E)
NJ
3.7% (VA)
4.2% (E)
12.3% (VA)
10.5% (E)
NC
2.1% (VA)
2.7% (E)
TN
11.3% (VA)
9.7% (E)
GA
2.4% (VA)
2.4% (E)
AL
1.6% (VA)
1.5% (E)
FL
2.3% (VA)
3.0% (E)

Note: VA = value added, E = employment.
Source: RRNA.

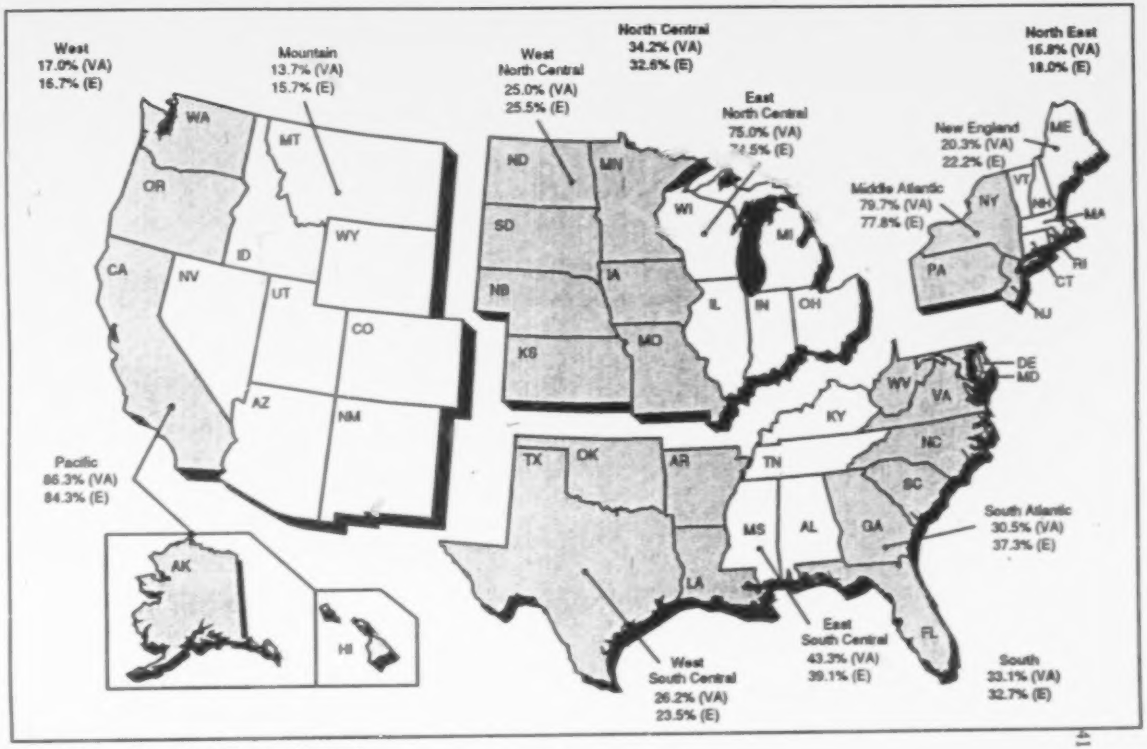
Table III-7. Value Added and Employment Contribution of U.S. Color TV Manufacturing, by Geographic Division and State, 1987

Geograpic division and state	Value added Amount (billion dollars)	Value added Percent distribution	Employment Amount (thousands)	Employment Percent distribution
New England	.284	3.2	9.5	4.0
Massachusetts	.133	1.5	4.5	1.9
Remainder of New England	.151	1.7	5.0	2.1
Middle Atlantic	1.111	12.5	33.2	14.0
New Jersey	.325	3.7	10.0	4.2
New York	.465	5.3	13.3	5.6
Pennsylvania	.322	3.6	10.0	4.2
Remainder of Middle Atlantic	N/A		N/A	
East North Central	2.270	25.6	57.5	24.3
Illinois	.587	6.6	15.0	6.3
Indiana	1.093	12.3	24.8	10.5
Michigan	.193	2.2	6.0	2.5
Ohio	.299	3.4	8.7	3.7
Remainder of East North Central	.098	1.1	3.0	1.3
West North Central	.757	8.6	19.7	8.3
Missouri	.501	5.7	12.1	5.1
Remainder of West North Central	.256	2.9	7.6	3.2
South Atlantic	.893	10.1	28.9	12.2
Florida	.203	2.3	7.2	3.0
Georgia	.210	2.4	5.6	2.4
North Carolina	.181	2.0	6.4	2.7
Remainder of South Atlantic	.299	3.4	9.7	4.1
East South Central	1.269	14.3	30.3	12.8
Alabama	.139	1.6	3.7	1.5
Tennessee	1.002	11.3	23.0	9.7
Remainder of East South Central	.128	1.4	3.7	1.6
West South Central	.769	8.7	18.2	7.7
Arkansas	.237	2.7	5.5	2.3
Texas	.363	4.1	9.1	3.8
Remainder of West South Central	.169	1.9	3.7	1.6
Mountain	.205	2.3	6.2	2.6
Pacific	1.295	14.6	33.4	14.1
California	1.158	13.1	29.5	12.5
Remainder of Pacific	.137	1.5	3.8	1.6
Total	8.853	100.0	237.0	100.0

Note: N/A means not applicable; items may not sum to totals due to rounding.
Source: Table A-2.

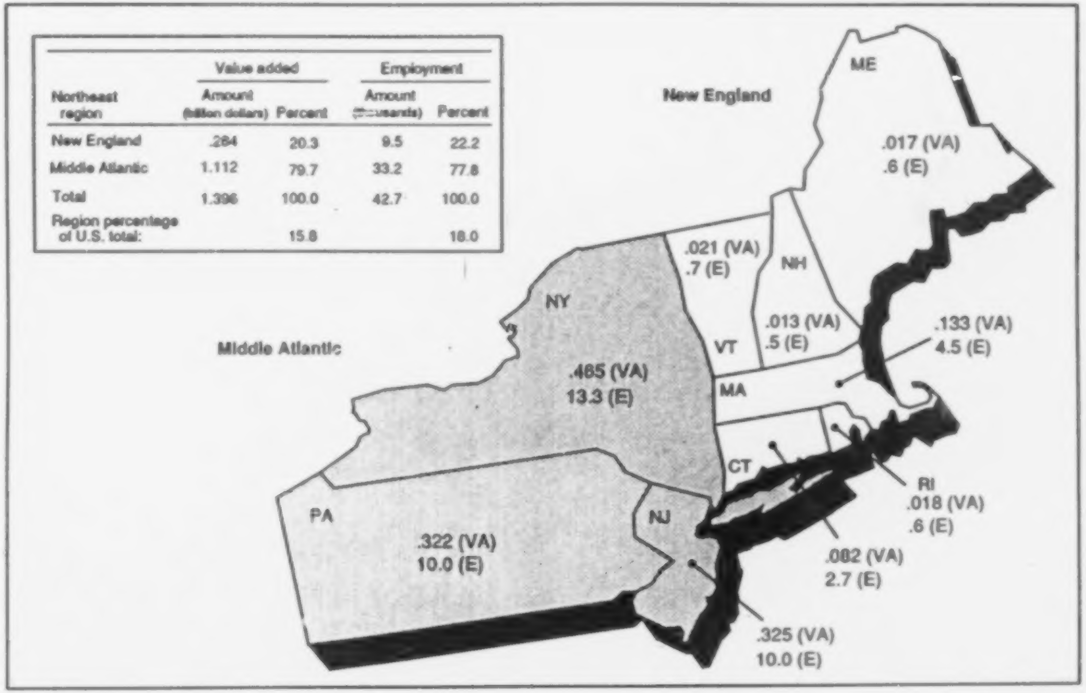
manufacturing in the United States is concentrated in the midwestern (Illinois, Indiana, Missouri) and southern states (Alabama, Arkansas, Georgia, Tennessee, Texas): about two-thirds of the industry's value added and employment contributions accrue in these regions of the country. The remainder is evenly divided between the western region, which has a substantial manufacturing enclave in California and some activity in Washington, and the northeastern region, which has a relatively small but still significant TV-producing state, New Jersey, and the substantial population concentration around New York. Figures III-5 through III-9 provide some of the detail for the states that make up each of the regions of the country.

Figure III-5. Percentage of Total Value Added and Employment Contribution of U.S. Color TV Manufacturing, 1987


West
17.0% (VA)
16.7% (E)
Mountain
13.7% (VA)
15.7% (E)
West
North Central
25.0% (VA)
25.5% (E)
North Central
34.2% (VA)
32.6% (E)
East
North Central
75.0% (VA)
74.5% (E)
North East
15.8% (VA)
18.0% (E)
New England
20.3% (VA)
22.2% (E)
Middle Atlantic
79.7% (VA)
77.8% (E)
WA
OR
CA
NV
ID
MT
WY
UT
CO
AZ
NM
ND
SD
NB
KS
MN
IA
MO
WI
MI
IL
IN
OH
NY
PA
VT
NH
ME
MA
RI
CT
NJ
DE
MD
WV
VA
KY
TN
NC
SC
GA
AL
MS
LA
AR
OK
TX
FL
AK
HI
Pacific
86.3% (VA)
84.3% (E)
South Atlantic
30.5% (VA)
37.3% (E)
East
South Central
43.3% (VA)
39.1% (E)
West
South Central
26.2% (VA)
23.5% (E)
South
33.1% (VA)
32.7% (E)

Note: VA = value added, E = employment.
Source: RRNA.

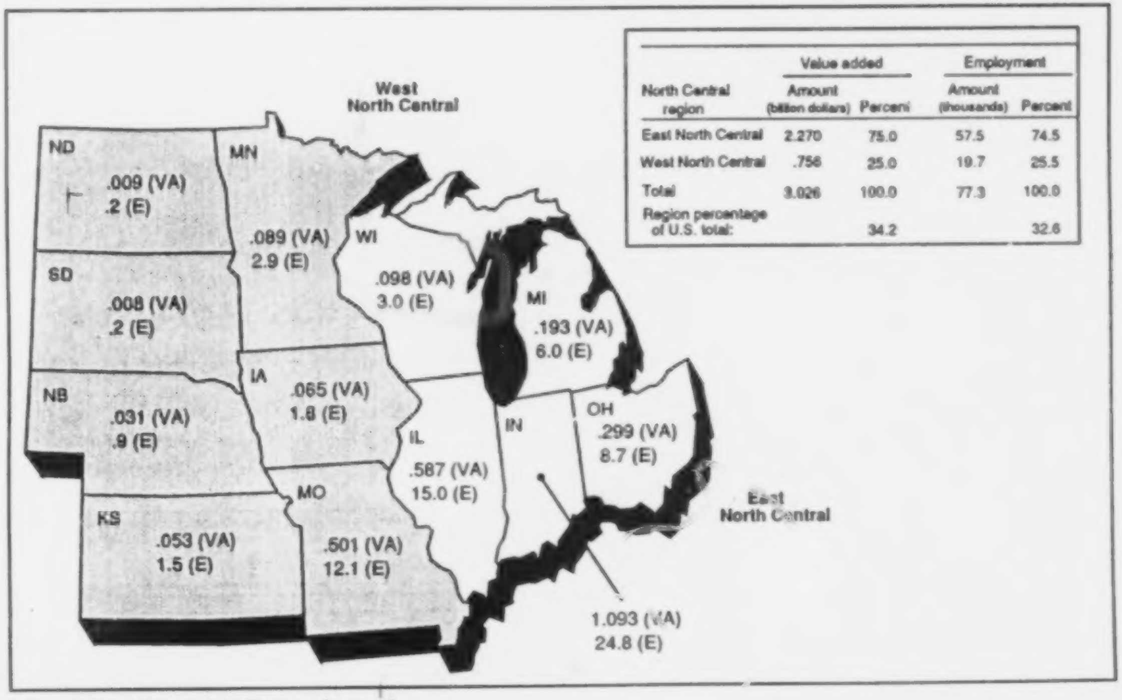
Figure III-6. Value Added and Employment Contributions of U.S. Color TV Manufacturing, Northeast Region, 1987


New England
Middle Atlantic
ME
.017 (VA)
.6 (E)
NH
.013 (VA)
.5 (E)
VT
.021 (VA)
.7 (E)
MA
.133 (VA)
4.5 (E)
RI
.018 (VA)
.6 (E)
CT
.082 (VA)
2.7 (E)
NY
.465 (VA)
13.3 (E)
NJ
.325 (VA)
10.0 (E)
PA
.322 (VA)
10.0 (E)

Northeast region	Value added		Employment	
	Amount (billion dollars)	Percent	Amount (thousands)	Percent
New England	.284	20.3	9.5	22.2
Middle Atlantic	1.112	79.7	33.2	77.8
Total	1.396	100.0	42.7	100.0
Region percentage of U.S. total:		15.8		18.0

Note: VA = value added, E = employment.
Source: RRNA.

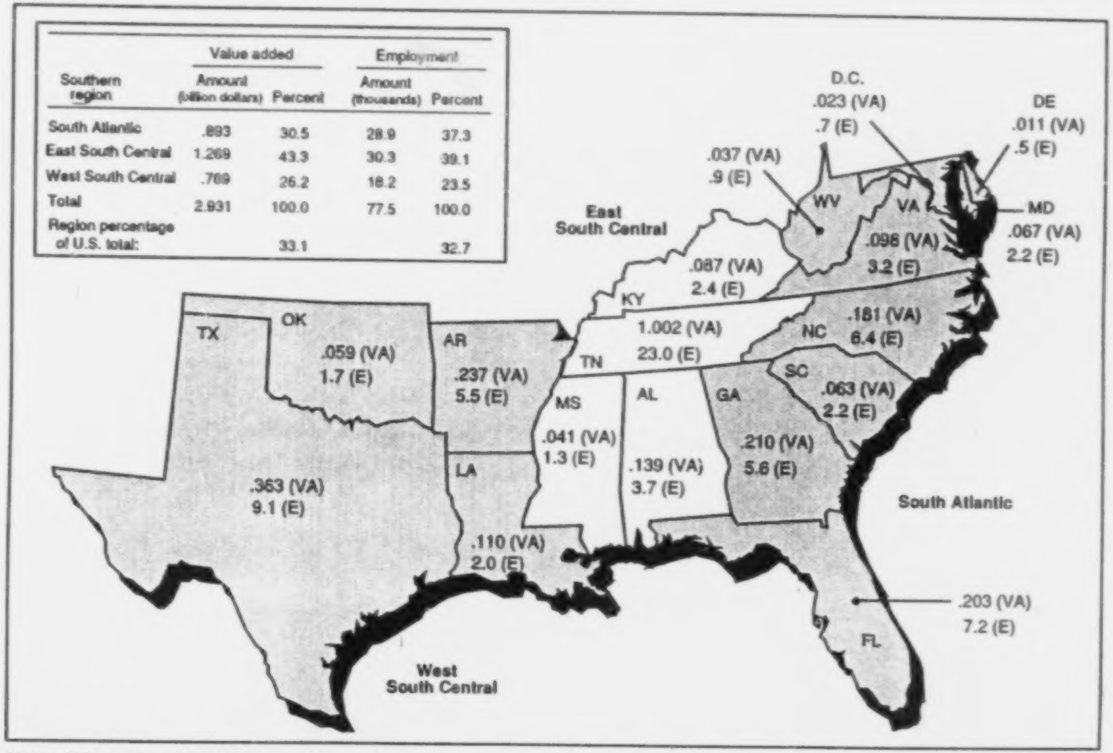
Figure III-7. Value Added and Employment Contributions of U.S. Color TV Manufacturing, North Central Region, 1987


West North Central
ND
.009 (VA)
.2 (E)
MN
.089 (VA)
2.9 (E)
SD
.008 (VA)
.2 (E)
WI
.098 (VA)
3.0 (E)
MI
.193 (VA)
6.0 (E)
IA
.065 (VA)
1.8 (E)
NB
.031 (VA)
.9 (E)
IL
.587 (VA)
15.0 (E)
IN
OH
.299 (VA)
8.7 (E)
MO
KS
.053 (VA)
1.5 (E)
.501 (VA)
12.1 (E)
1.093 (VA)
24.8 (E)
East North Central

North Central region	Value added Amount (billion dollars)	Percent	Employment Amount (thousands)	Percent
East North Central	2.270	75.0	57.5	74.5
West North Central	.756	25.0	19.7	25.5
Total	3.026	100.0	77.3	100.0
Region percentage of U.S. total:		34.2		32.6

Note: VA = value added, E = employment.
Source: RRNA.

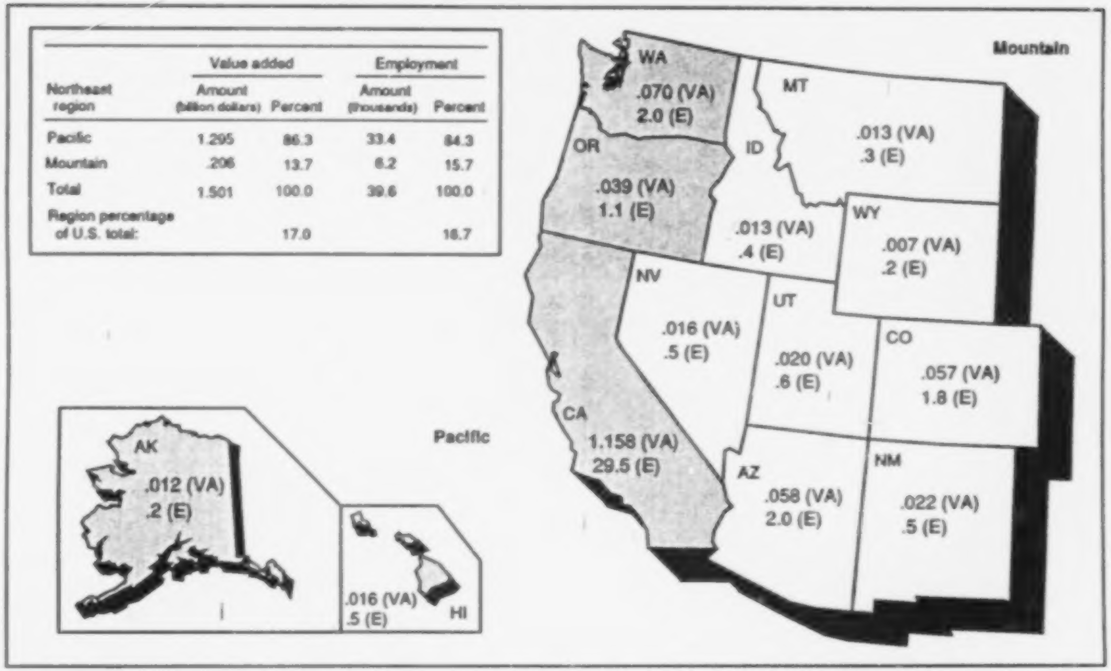
Figure III-8. Value Added and Employment Contributions of Color TV Manufacturing, Southern Region, 1987


D.C.
.023 (VA)
.7 (E)
DE
.011 (VA)
.5 (E)
.037 (VA)
.9 (E)
WV
VA
.098 (VA)
3.2 (E)
MD
.067 (VA)
2.2 (E)
East
South Central
KY
.087 (VA)
2.4 (E)
TN
1.002 (VA)
23.0 (E)
NC
.181 (VA)
6.4 (E)
SC
.063 (VA)
2.2 (E)
GA
.210 (VA)
5.6 (E)
AL
.139 (VA)
3.7 (E)
MS
.041 (VA)
1.3 (E)
AR
.237 (VA)
5.5 (E)
LA
.110 (VA)
2.0 (E)
TX
OK
.059 (VA)
1.7 (E)
.363 (VA)
9.1 (E)
South Atlantic
FL
.203 (VA)
7.2 (E)
West
South Central

Southern region	Value added: Amount (billion dollars)	Value added: Percent	Employment: Amount (thousands)	Employment: Percent
South Atlantic	.893	30.5	28.9	37.3
East South Central	1.269	43.3	30.3	39.1
West South Central	.769	26.2	18.2	23.5
Total	2.931	100.0	77.5	100.0
Region percentage of U.S. total:		33.1		32.7

Note: VA = value added, E = employment.
Source: [illegible]

Figure III-9. Value Added and Employment Contributions of U.S. Color TV Manufacturing, Western Region, 1987


Mountain
WA
.070 (VA)
2.0 (E)
MT
.013 (VA)
.3 (E)
OR
.039 (VA)
1.1 (E)
ID
.013 (VA)
.4 (E)
WY
.007 (VA)
.2 (E)
NV
.016 (VA)
.5 (E)
UT
.020 (VA)
.6 (E)
CO
.057 (VA)
1.8 (E)
CA
1.158 (VA)
29.5 (E)
AZ
.058 (VA)
2.0 (E)
NM
.022 (VA)
.5 (E)
Pacific
AK
.012 (VA)
.2 (E)
.016 (VA)
.5 (E)
HI

	Value added		Employment	
Northeast region	Amount (billion dollars)	Percent	Amount (thousands)	Percent
Pacific	1.295	86.3	33.4	84.3
Mountain	.206	13.7	6.2	15.7
Total	1.501	100.0	39.6	100.0
Region percentage of U.S. total:		17.0		16.7

Note: VA = value added, E = employment.
Source: RRNA.

IV. HIGH DEFINITION TV'S POTENTIAL ECONOMIC IMPACT ON TELEVISION MANUFACTURING IN THE UNITED STATES

The potential income and employment implications of high definition television (HDTV) for the U.S. economy are significant. RRNA forecasts that more than 13 million HDTV receiver sets will be purchased by U.S. consumers in the year 2003: 92 percent of these sets will be manufactured in the United States. Given current manufacturing technologies and economies, the production and sale of U.S.-made HDTVs will contribute $23 billion to GNP and employ 232,000 workers. Based on the assumptions contained herein, the manufacture, distribution, and sale of U.S.-made HDTVs will increase the contribution of TV manufacturing to GNP by $6.2 billion more than the amount that would be realized if HDTV were not commercialized. The net addition to GNP is the result of the higher price of an HDTV relative to the average TV set; the same number of TVs will be produced and sold, about 28 million, and the same number of workers will be employed in the economy, nearly 500,000, whether or not HDTV is introduced into the U.S. consumer electronics market.

HDTV will make additional contributions to the economy through substantial opportunities created in the development, installation, and operation of communication transmission equipment and delivery systems.

The color TV manufacturing industry is in the midst of a major innovation in technology. HDTV is a configuration of sophisticated video and audio technologies that results in a significantly upgraded wide aspect TV picture and sound quality when compared with the current National Television Standards Committee (NTSC) delivery system and TV receivers. At last count, more than 20 different HDTV systems are under development for consideration as the U.S. transmission standard. High definition television is the most advanced of the advanced technologies under development. Less complex forms of advanced TV are improved definition television (IDTV) and enhanced (or extended) definition television (EDTV).

The introduction of HDTV into the U.S. consumer product market is rapidly approaching. This new technology will affect virtually all segments of the TV industry: television program and software production, transmission systems, reception and display equipment, and complementary consumer products. HDTV production equipment has been commercialized since 1983, and an HDTV transmission standard is in development. The availability of HDTV consumer products is not far behind. TV receivers using IDTV technologies are already in the market.

HDTV Production and Sales Forecast

The production and sale of high definition televisions will have substantial effects on color TV manufacturing in the United States. In the year 2003, 13 million HDTV units will be sold, a fraction less than the number of color TVs produced and sold in the United States in 1987; more than 12 million of the 13 million HDTVs will be manufactured in the United States. Sales of U.S.-made HDTVs will generate more than 3.6 times the retail value of U.S. production in 1987, and about 3.3 times the industry's contribution to GNP. Household penetration will reach 25 percent by the beginning of the 21st century.

RRNA's HDTV forecast and underlying roll-out scenario are based on data and information collected by surveys of U.S. television manufacturers and firms developing HDTV technologies and products. Secondary sources, including studies, reports, articles in the trade and popular press, and statistical time series and cross-sectional databases, were also used to project the production and sale of HDTVs and the dimensions of the U.S. color television market. The information collected in the interviews and from the other sources was used to formulate a number of realistic and necessary assumptions that constitute the foundation of the forecast.

Foundation of HDTV Forecast: Assumptions and Methodology

Assumptions about future events are critical to the validity and reliability of a forecast. Ten major assumptions underlie RRNA's HDTV forecast:

- NTSC Compatibility -- HDTV technology will not make NTSC receivers obsolete. Viewers using NTSC sets will continue to be able to receive broadcasts, cablecasts, and satellite-delivered programs, but may not be able to receive all signals transmitted.

- Product Commercialization -- HDTV technology will first be commercialized as a high end product in screen sizes of 30 inches and larger, absorbing the 26- to 29-inch screen segment of the market. Once this transition is completed and production economies are achieved, HDTVs will be offered in 20- to 25-inch screen sizes.

- Production Location -- High end, 30-inch and larger HDTV sets sold in the United States will be produced in the United States. Transportation costs make offshore production sites for picture tubes and receiver sets uneconomical. The smaller, 20- to 25-inch HDTVs sold in U.S. markets will be manufactured both at home and abroad; for the forecast it is assumed that one-third of these smaller sets will be imports.

- Timing -- IDTV units are currently available in the market. Transmission standards will be set and settled in time for the first noticeable sales of HDTV sets to occur in 1993. Smaller screen (20- to 25-inch) HDTVs will first appear in the market in 1999.

- Consumer Adoption -- Early adopters will be attracted to the large screen sets because of the wide screen display, compact disk (CD) quality sound system, and especially the high resolution picture that early consumer research indicates can be perceived and appreciated fully in screen sizes of 30 inches and larger. HDTV sets will completely replace NTSC 30-inch and larger sets in the market within six years, following the color TV penetration curve initiated in 1961. The wide screen and CD-quality stereo sound features will attract a market for 20- to 25-inch sets once production economies are achieved and smaller sets can be brought to the market at a reasonable price differential in comparison with NTSC sets in this market segment.

- Software Availability -- Compatible programming and software will be available as HDTV products are introduced in the market.

- Average Retail Price -- High definition television sets in large screen sizes will first be sold at an average unit price of $2,500, 60 percent higher than a comparable 30-inch NTSC set. The initial $2,500 retail price, about the same as the average price of a color TV in 1961 if it were purchased in 1987, is supported by expected differences between an HDTV set and an NTSC set in the complexity of design and material costs. Retail prices for these high end products will decline at a rate faster than the rate of decline for color TVs from their 1961 average price, as production economies are achieved in HDTV set and picture tube manufacturing.[9]

- Domestic Content -- On average, the U.S. TV pipeline will contribute 85 percent of the retail price of an HDTV set, reflecting the same domestic contribution by large screen sets currently produced in the United States. The 15 percent imported content includes principally the costs of the chassis and electronic circuitry, tuner, and royalty fee.[10] The royalty fee, which represents only 1.5 percent of the retail price, may remain in the United States if the product is commercialized with a U.S. design.

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[9] The picture tube is the single most expensive part of a color TV set. It costs about 25 percent of the retail price. If the cost of the HDTV picture tube can be reduced by 25 percent from 1993 to 1998, then the average price of a 30-inch or larger HDTV set would be only 21 percent higher than the price of an NTSC set of the same screen size.

- General Economic and Social Trends -- Long-term trends in GNP growth, household formation, and other factors influencing TV sales will continue throughout the forecast period.
- Related Technological Innovations -- There will not be any new technological innovations that will have material effects on the production and sale of HDTV sets. In particular, commercialization of HDTV will not impinge on the HDTV segment of the market.

The production and sale of HDTVs is projected by applying market share estimates for HDTV and NTSC products to a forecast of the sale of color TVs in the United States to the year 2003 (15 years from now and 10 years after the expected introduction of HDTV in 1993). Future sales of color TVs are projected on the basis of continuing long-term trends in GNP, household formation, and other factors influencing the sale of TV sets in the United States. HDTV is a substitute product for NTSC sets rather than a unique, entirely new product. The number of color TVs sold will not be affected by the introduction of HDTV.[11]

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10. This assignment of the foreign content is a simplifying assumption. Microprocessors or customized integrated circuits used in HDTVs may be manufactured in the United States but the chassis assembled in another country; the electronic elements contained in the picture tube may be purchased from foreign suppliers, but the tube manufactured in the United States.

11. The same was true with regard to color TVs in the 1960s.

A view of TV product mix and the changes in market share that may be associated with HDTV are displayed in Figure IV-1. Initial (1988) and end-of-forecast (2003) expected market shares by screen size are set out in Table IV-1, along with estimated retail prices, assumed production sites, and domestic content of the different size sets. As can be noted, the commercialization of large screen HDTVs will result in the elimination of NTSC sets in the 26- to 29-inch screen size. At present, picture tubes in the 26-inch size are being phased out in favor of 27-inch and larger screens. In spite of the initial high price of a 30-inch and larger HDTV, the high resolution picture in combination with the wide screen and CD-quality sound will attract innovators who will prefer the large screen HDTV to a large screen NTSC set.[12] In addition to these HDTV developments, an expansion of the market share of small screen (12 inches and smaller) TVs can be expected. These sets will be of the wristwatch and pocket TV variety, which are relatively inexpensive, and other types of small portable sets that will be used more in the future. These small TVs will take the place of today's black and white sets.

The average retail prices listed in Table IV-1 reflect expected declines in the prices of TVs. The $1,815 expected price of a large screen HDTV in 2003 is equivalent to a price of $1,050 in 1987.[13] The allocated shares by production site are based on the current status of color TV manufacturing -- at present, virtually all sets 20 inches and larger are made in the United States, virtually all sets 12 inches and smaller are imported, and about

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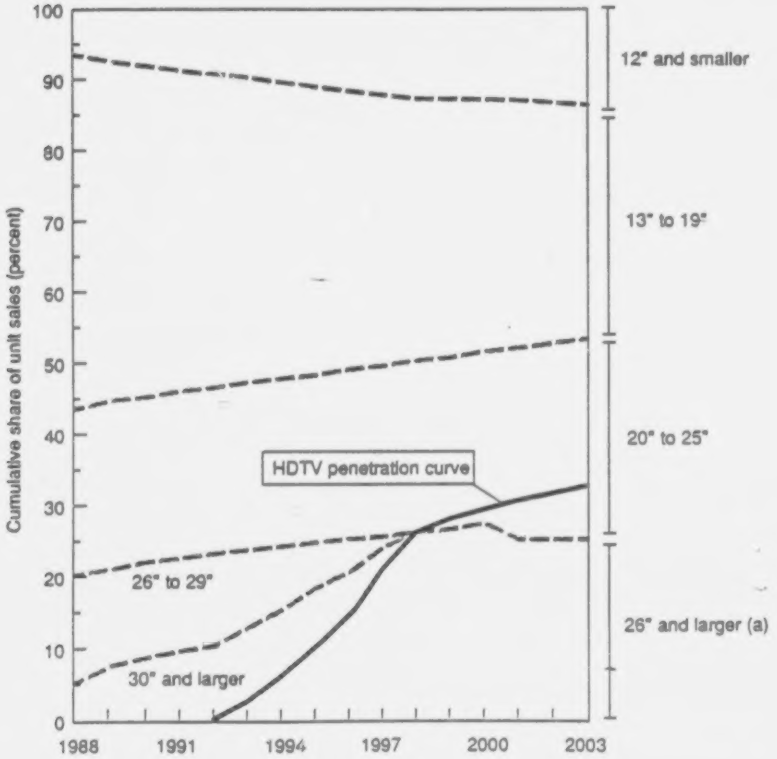
[12] Some of the increase in the 30-inch and larger share of the market will result from HDTV's stimulation of projection TV sales. Projection TVs currently constitute about 1 percent of the TVs sold in the United States and could increase to 5 percent with HDTV. The price for an HDTV projection TV would be comparable with a direct view HDTV, since a projection TV uses a projection screen for display and does not require a large picture tube.

[13] This is based on an average annual inflation rate of 3.5 percent.

Figure IV-1. U.S. Color TV Market With HDTV, Market Share by Screen Size, 1988 through 2003



a. Beginning in 1998 these include only sets 30 inches and larger.
Source: RRNA.

Table IV-1. Market Shares, Average Retail Prices, Production Site, and Domestic Content of HDTV and NTSC Sets, if HDTV is Commercialized, by Screen Size, 1988 and 2003

Screen size	Unit sales (percent)				Average retail price (dollars)			Production site (percent)				Domestic content of U.S. production (a) (percent)	
		2003				2003		HDTV		NTSC			
	1988	HDTV	NTSC	Total	1988	HDTV	NTSC	U.S.	Foreign	U.S.	Foreign	HDTV	NTSC
12 inches and smaller	7.0	0.0	13.9	13.9	244	N.A.	191	N.A.	N.A.	0.0	100.0	N.A.	N.A.
13 to 19 inches	49.0	0.0	33.1	33.1	292	N.A.	270	N.A.	N.A.	50.0	50.0	N.A.	91.0
20 to 25 inches	24.0	7.5	20.5	28.0	444	488 (b)	410	67.0	33.0	100.0	0.0	85.0	91.0
26 to 29 inches	15.0	0.0	0.0	0.0	625	N.A.	N.A.	N.A.	N.A.	100.0	0.0	85.0	85.0
30 inches and larger	5.0	25.0	0.0	25.0	1,725	1,815 (c)	N.A.	100.0	0.0	100.0	0.0	85.0	85.0
Total	100.0	32.5	67.5	100.0									

Notes: All 1988 products are NTSC. Figures for HDTV production site and domestic content are for 2003; figures for NTSC production site and domestic content are for 1988 and 2003. N.A. means not applicable.

a. Value added as a percentage of retail price.

b. $506 initial price in 1999.

c. $2,500 initial price in 1993.

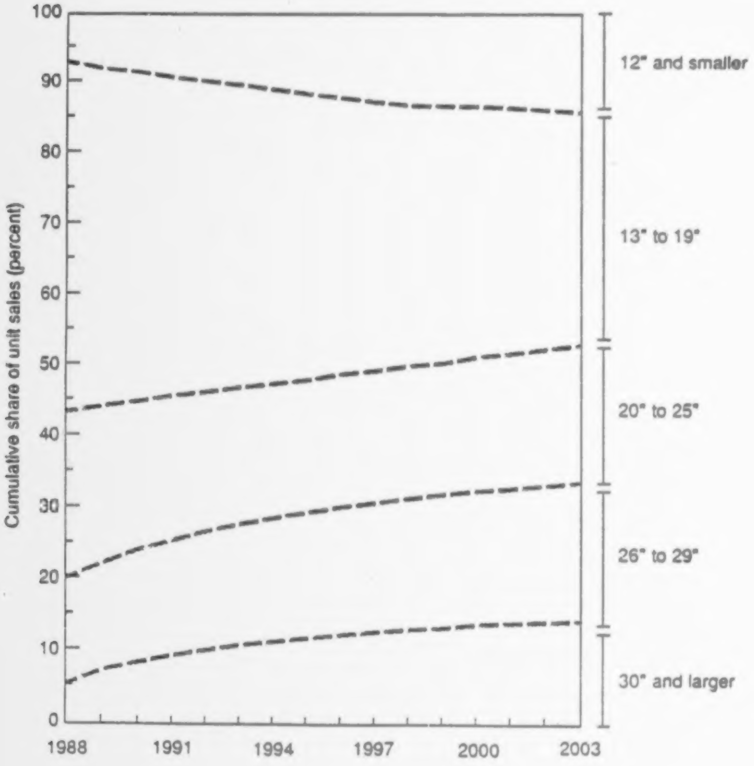
Source: RRNA.

50 percent of sets in the 13- to 19-inch category are manufactured in the United States and 50 percent are imported. The only exception is the assumed 33 percent import share for HDTVs in the 20- to 25-inch screen size. Similarly, the value of domestic content, as a percentage of retail price, is assumed to be the same as current U.S. production within screen size, with the one exception that 20- to 25-inch HDTVs are assumed to have the same domestic content as the larger HDTVs.

To evaluate the net impact of HDTV on U.S. color TV manufacturing, a forecast of the U.S. color TV market in the absence of HDTV, i.e., if HDTV were not commercialized, was also prepared. Figure IV-2 illustrates the expected changes in market shares, by screen size, if HDTV were not brought to the market during the forecast period. Initial and end-of-forecast-period market shares, average retail prices, production sites, and the share of the value of U.S. production that is domestically produced (value added) are summarized in Table IV-2. As in the HDTV scenario, average retail prices reflect expected declines in the prices of TVs; also, the allocated shares of production by location and the value of domestic content as a percent of retail price are assumed to be the same as current production within screen size.

The principal difference between the two scenarios (with and without HDTV) is the allocation of market share for sets 20 inches and larger between the 20- to 25-inch and the 26-inch and larger segments. If HDTV sets were not produced and sold in the United States, the 20- to 25-inch category would maintain about 20 percent of the number of units sold, while the 26-inch and larger category would increase its share from 20 percent to nearly 34 percent in 2003. With HDTV, the 20- to 25-inch segment will increase from 24 percent to 28 percent while the share attributable to the 26-inch and larger category will increase from 20 percent to 25 percent by the end of the

Figure IV-2. U.S. Color TV Market Without HDTV, Market Share by Screen Size, 1988 through 2003



Source: RRNA.

Table IV-2. Unit Sales, Average Retail Price, Production Site, and Domestic Content of U.S. Production, in the Absence of HDTV Commercialization, by Screen Size, 1988 and 2003

Screen size	Unit sales (percent) 1988	Unit sales (percent) 2003	Average retail price (dollars) 1988	Average retail price (dollars) 2003	Production site (percent) U.S.	Production site (percent) Foreign	Domestic content of U.S. production (a) (percent)
12 inches and smaller	7.0	13.9	244	191	0.0	100.0	N.A.
13 to 19 inches	49.0	33.1	292	270	50.0	50.0	91.0
20 to 25 inches	24.0	19.4	444	410	100.0	0.0	91.0
26 to 29 inches	15.0	19.3	625	524	100.0	0.0	85.0
30 inches and larger	5.0	14.3	1,725	1,414	100.0	0.0	85.0
Total	100.0	100.0					

Note: Figures for production site and domestic content apply to 1988 and 2003. N.A. means not applicable.

a. Value added as a percentage of retail price.

Source: RRNA.

forecast period, peaking in the year 2000 at about 27.5 percent.[14] As HDTV is commercialized in the 30-inch and larger screen size, consumers who would have purchased 26- to 29-inch TVs will be divided between those upgrading to a higher priced 30-inch or larger HDTV set and those purchasing a lower priced 20- to 25-inch NTSC set.

Before presenting the implications of these market share expectations for the value of retail sales, U.S. production, and value added, it is important to note that these assumptions represent only one of several possible HDTV roll-out scenarios, and only one of a number of different expectations about market shares if HDTV were not commercialized. Other scenarios were explored which yielded results that are either more or less impressive and have more or less dramatic but similar implications in terms of the impact of HDTV on the U.S. color TV manufacturing industry.

Forecast Results

The HDTV forecast results are summarized in Table IV-3 for selected years. Results for each year in the forecast period, from 1989 through 2003, are presented in Appendix B, Table B-1 (forecast results for the "without HDTV" scenario are contained in Table B-2). The broad dimensions of the forecast results are summarized in Figure IV-3 for the year 2003. By the end of the forecast period, 13.1 million of the 40.2 million TVs sold in the United States (32.5 percent) will be HDTVs[15]; 12.1 million HDTVs will be

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[14] By 1998, this segment will include only 30-inch and larger HDTVs.

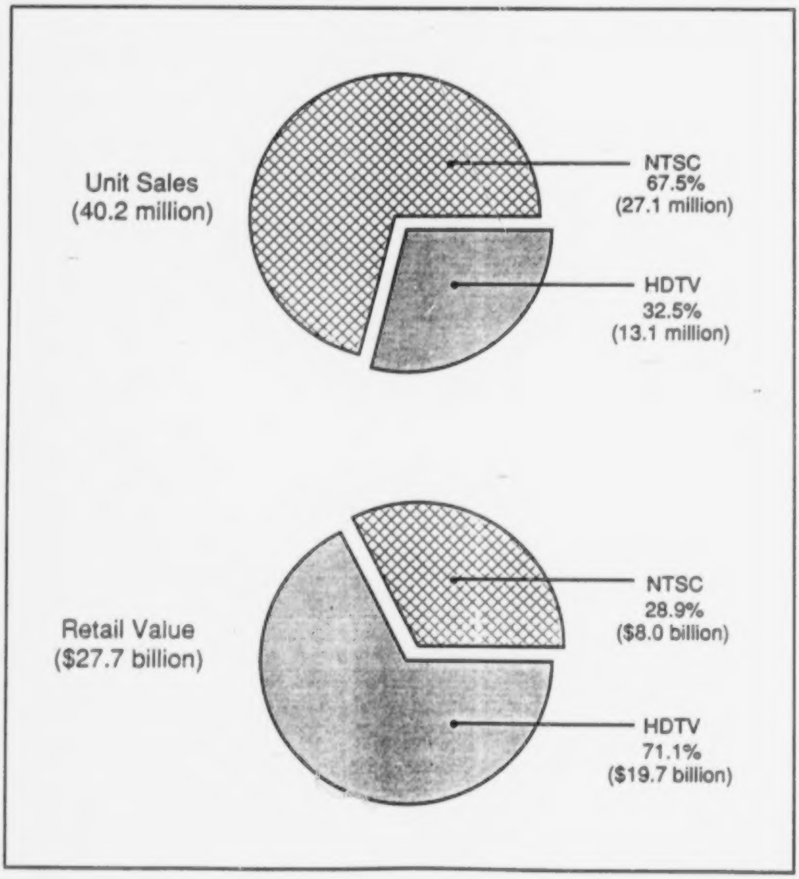
[15] Projected annual sales of color TVs reflect the continuation of long-term trends in the factors that influence annual sales volume. Even so, the sales forecast for 2003, 40.2 million sets, is twice the number that will be sold in 1988 and may be viewed as an optimistic, upper-bound, projection. Although per-capita television consumption has doubled in the last 15 years, a continuing increase in sales per population will be moderated by the increasing useful life of a TV set and potential saturation of the population. If per-capita TV consumption remains constant during the next 15 years, then annual sales could be expected to reach only about 26 million sets in 2003.

Table IV-3. Forecast of Color TV and HDTV Unit Sales, Retail Value, U.S. Production, Retail Value of U.S. Production, and Value Added by U.S. Production, Selected Years
(Units in millions and dollars in billions)

Item	1989	1993	1998	2000	2003
Unit sales					
Total (units)	21.3	26.0	32.7	35.6	40.2
HDTV					
Number (units)	0.0	0.7	8.5	10.4	13.1
Percent of total	0.0	2.5	26.0	29.3	32.5
Retail value					
Total (dollars)	9.9	13.9	23.8	26.2	27.7
HDTV					
Amount (dollars)	0.0	1.6	16.3	18.5	19.7
Percent of total	0.0	11.7	68.6	70.8	71.1
U.S. production					
Total (units)	14.6	17.8	22.4	24.4	27.0
HDTV					
Number (units)	0.0	0.7	8.5	10.2	12.1
Percent of total	0.0	3.6	37.9	41.8	44.8
Retail value of U.S. production					
Total (dollars)	8.0	11.8	21.3	23.4	24.4
HDTV					
Amount (dollars)	0.0	1.6	16.3	18.4	19.2
Percent of total	0.0	13.8	76.7	78.7	78.8
Value added by U.S. production (a)					
Total (dollars)	7.1	10.3	18.4	20.2	21.1
HDTV					
Amount (dollars)	0.0	1.4	13.9	15.7	16.3
Percent of total	0.0	13.4	75.4	77.5	77.6

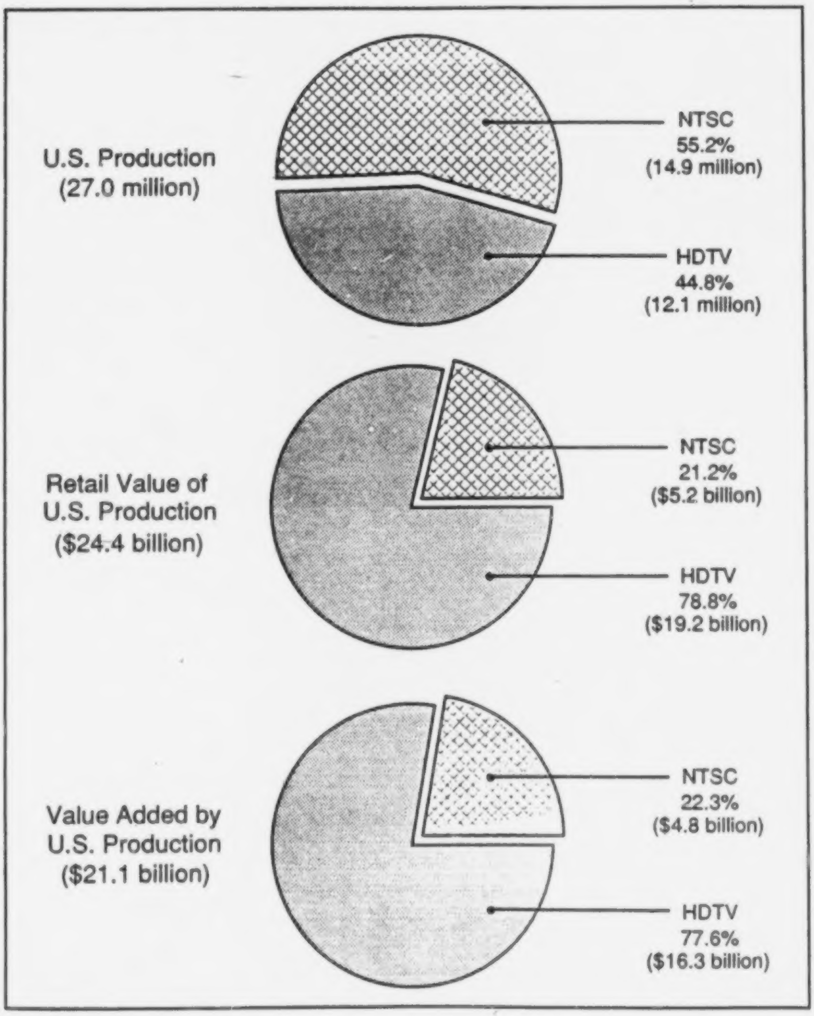
Note: Percentages may not calculate due to rounding.
a. Domestic content portion of retail value.
Source: Table A-1.

Figure IV-3. Forecast of Color TV and HDTV Unit Sales, Retail Value, U.S. Production, Retail Value of U.S. Production and Value Added by U.S. Production, 2003



(continued)

Figure IV-3 (continued).



Source: RRNA.

manufactured in the United States. Total HDTV sales will have a retail value of $19.7 billion (71 percent of total color TV retail sales). Sales of U.S. made HDTVs will account for 79 percent of the total retail value of U.S. color TV production, representing a contribution of $16.3 million to the U.S. economy (78 percent of total U.S. value added by color TV manufacturing).

Household Penetration

A closer look at the first phase of HDTV commercialization, from introduction in 1993 through the complete penetration of the large screen, 30-inch and larger segment of the market in 1998, helps shed some light on the proverbial "chicken and egg" question: will there be sufficient household penetration to warrant investment in HDTV transmission and delivery systems? Table IV-4 compares cumulative sales of HDTV units with estimates of the number of households for the first six years of HDTV sales. According to these figures, about 10 percent of U.S. households will have a large screen HDTV set by the end of 1996, within four years of the introduction of the product to the color TV market. Twenty-five percent household penetration can be expected by the end of the 20th century.

Net Impact on U.S. Television Manufacturing

The forecast results are impressive and significant: household penetration will be 10 percent within four years of market introduction; HDTVs will account for almost one-third of all the TVs sold in the United States in the year 2003; HDTVs manufactured in the United States will account for 45 percent of all domestic color TV production and 79 percent of the retail value of U.S. production. A comparison of the HDTV forecast with a forecast of U.S. color TV production and sales if HDTV were not introduced in the market provides a basis for assessing the net impact of HDTV on the U.S. economy. The figures are set out in Table IV-5. HDTV will increase

Table IV-4. Projected HDTV Sales and U.S. Households, 1993 through 1998

Year	HDTV units (millions) Sales	 Cumulative sales	Households (a) (millions)	Cumulative sales as a percent of households
	(1)	(2)	(3)	(4)=(2)/(3)
1993	0.7	0.7	99.8	0.7
1994	1.6	2.3	101.3	2.3
1995	3.3	5.6	102.8	5.4
1996	4.8	10.4	104.3	10.0
1997	6.5	16.9	105.8	16.0
1998	8.5	25.4	107.2	23.7

a. Interpolated from household projections series A published in Statistical Abstract of the United States, 1988, Table 57, p. 43. Series A assumes a continuation of both past householder proportions and recent moderation in marriage and divorce trends, but changes spanning the last 25 years are given more weight.

Source: RRNA.

Table IV-5. Comparison of U.S. Color TV Sales and Production With and Without HDTV Commercialization, 2003

Screen size	U.S. sales and production with HDTV commercialization				U.S. sales and production without HDTV commercialization			
		U.S. production				U.S. production		
	Unit sales	Units produced	Retail value	Value Added	Unit sales	Units produced	Retail value	Value added
	- - - - millions - - - -		- - - billion dollars - - -		- - - - millions - - - -		- - - billion dollars - - -	
12 inches and smaller	5.6	0.0	0.0	0.0	5.6	0.0	0.0	0.0
13 to 19 inches	13.3	6.7	1.8	1.6	13.3	6.7	1.8	1.6
20 to 25 inches	11.3	10.3	4.4	3.9	7.8	7.8	3.2	2.9
26 inches and larger	10.1	10.1	18.2	15.5	13.5	13.5	12.2	10.4
Total	40.2	27.0	24.4	21.1	40.2	28.0	17.2	14.9

Note: Totals may not sum due to rounding.
Source: RRNA.

substantially the retail value of U.S. production of TVs and the contribution of that production to GNP; these indicators will be about 42 percent larger with HDTV ($24.4 billion and $21.1 billion, respectively) than without HDTV ($17.2 billion and $14.9 billion, respectively).

Although U.S. television manufacturers will be producing higher priced state-of-the-art receivers, if current production locations remain the same U.S. manufacturers will be producing about the same number of sets as they would if HDTV were not brought to the market. In addition, under either scenario, sets with screen sizes of 20 inches and larger will constitute 76 percent of all receivers manufactured in the United States. Under the HDTV forecast, these units will be about evenly divided between the 20- to 25-inch and the 26-inch and larger (actually 30-inch and larger) segments; in the view of U.S. television manufacturing in the absence of HDTV, a greater proportion of the 20-inch and larger sets, 63 percent, would be in the larger screen size while only 37 percent would be in the 20- to 25-inch category. The comparison indicates that larger screen (26-inch and larger) sizes will constitute a smaller share of production with HDTV than if HDTV were not brought to the market.

Impacts of HDTV on the U.S. TV Pipeline

The production of high definition televisions will constitute a significant segment of the U.S. color TV manufacturing industry in the year 2003, about the same size as the current color TV pipeline and similar in structure. About 129,000 workers will be employed in the manufacture and sale of U.S.-made HDTV sets, by their suppliers and buyers and others in the production and distribution chain, and by other firms supplying goods and services used in the production process.

Total employment in the U.S. TV pipeline (i.e., the number of workers employed directly by the receiver set industry, plus those working upstream and downstream at other stations in the pipeline), estimated to be about 275,000, will be the same whether or not HDTV is commercialized in the United States. This figure assumes the continuation of input sourcing and current distribution methods used for color TV manufacturing today, as well as present production economies and technologies.[16] These employment estimates also presume that television manufacturing in the United States will have achieved a "steady state" by the year 2003, the end of the forecast period. Employment will undoubtedly increase in the short run as research and engineering are undertaken in the receiver set, picture tube, electronic components, and related industries to bring HDTV into the consumer market.

Direct and Indirect Employment Requirements of HDTV

The number of workers currently employed at the successive stages of the TV pipeline, about 132,000,[17] represents a baseline for estimating the size of the U.S. work force needed to produce HDTVs in 2003. The number of HDTV units that will be sold in the year 2003, 13.1 million sets, is about the same as RRNA's estimate of the number of color TVs produced and sold in the United States in 1987.[18] About 92 percent of these HDTV sets, or 12.1 million units, will be manufactured in the United States. Additional workers may not be required to produce and distribute HDTV sets because the product will be more expensive than the average TV set today.

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[16] Potential productivity improvements throughout the pipeline will ultimately reduce pipeline employment.

[17] Estimated by RRNA and reported in Chapter III; see pp. 31-33.

[18] RRNA estimates that 13.4 million color TVs were produced in the United States in 1987, based on the survey of U.S. color TV producers reported in Chapter II.

The 12.1 million HDTV units projected to be manufactured in the United States is about 90 percent of 1987 U.S. production. Ninety percent of the employment in the 1987 color TV pipeline establishes a baseline estimate of the workforce needed to manufacture and distribute HDTVs. Expected differences between HDTVs and the average color TV in 1987 in input sourcing and the physical characteristics of the product -- its size and complexity -- require some adjustments to the initial 90 percent baseline. An additional 8.5 to 10 percent in employment or, on average, a total of 128,800 workers, could be employed in the production and sale of 12.1 million U.S.-made HDTVs in 15 years. The derivation of this estimate is presented in Table IV-6. Total employment in U.S. color TV manufacturing in 1987 and that employment reduced across the board by 10 percent are shown as are the potential employment adjustments used to estimate the number of workers that will be employed in manufacturing HDTVs.

The HDTV production and sales forecast is predicated on the understanding that contributions to the product by U.S. manufacturing and distribution will amount to about 85 percent of the retail price of an HDTV set; the remaining 15 percent accounts for the foreign or imported content. Although 85 percent domestic content is significant, the domestic content of the average color TV made in the United States in 1987 was 91 percent. These differences will have some, albeit small, employment implications.[19]

- Picture tubes -- In 1987, about 90 percent of the picture tubes used in the manufacture of color TVs were sourced domestically. It is expected that all the picture tubes used in the larger screen HDTVs will be manufactured in the United States. This implies a potential increase in employment of 1,000 workers. Some of the 20- to 25-inch HDTVs will be imported, reducing the 1,000 worker adjustment (arbitrarily) by 10 percent to 900 workers.

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[19] These estimated employment adjustments employ the assumption noted in footnote 10.

Table IV-6. Employment in the TV Pipeline, Color TV in 1987 and HDTV in 2003

	Color TV employment in 1987 (1)	90 percent of 1987 color TV employment (2) = (1) x .9	Potential employment adjustment for HDTV (3)	HDTV employment in 2003 (4)=(2)+(3)
TV industries:				
Receiver sets	28,000	25,200	1,300	26,500
Picture tubes	10,100	9,100	1,400	10,500
Electronic components and parts	1,000	900	200	1,100
Furniture cabinetry	5,300	4,800	500	5,300
Subtotal - TV industries	44,400	40,000	3,400	43,400
Other industries:				
Manufacturing, other than TV industries	16,100	14,500	700	15,200
Wholesale trade	12,800	11,500	1,200	12,700
Retail trade	33,600	30,200	2,300	32,500
Services	16,300	14,700	1,500	16,200
Transportation, utilities, and communications	5,300	4,800	700	5,500
Other	3,200	2,900	400	3,300
Subtotal - Other industries	87,300	78,600	6,800	85,400
Total	131,700	118,600	10,200	128,800

Source: RRNA.

- Electronic components and parts (including circuitry, royalty fee, and tuner) -- These manufacturing inputs are expected to account for the 15 percent foreign content of HDTV sets although the license fee, which is only a small fraction of the total, may be paid to U.S. interests if a U.S. HDTV design is commercialized, even though the assembly of the chassis and circuitry may take place outside the United States. In 1987, electronic components and parts made in the United States accounted for 32 percent of the value of these parts used in domestic production. HDTVs will use customized integrated circuits and microprocessors, electronic products in which the U.S. electronic components industry has a technological and commercial advantage.[20] At the same time, the sourcing of electronic components and other basic materials used in manufacturing televisions is driven largely by changes in foreign exchange rates. On balance, a 20 percent adjustment in employment (200 workers) is used to account for the possibility of the domestic sourcing of customized ICs and other components unique to HDTV.

- Furniture cabinetry -- On average, 95 percent of the wood cabinets used in producing color TVs in 1987 came from domestic sources. All of the cabinets for HDTVs are expected to be made in the United States. This difference in domestic content implies an adjustment of 200 workers employed in manufacturing wood cabinets.

A fundamental assumption of the forecast is that HDTV technology will be commercialized and will have its greatest impact on sets with 30-inch and larger screen sizes. It is likely that the large size of the units and their picture tubes and cabinets will require a greater number of workers and more equipment to manufacture and move the parts and finished goods through the production chain and through the distribution, wholesaling, and retailing of the product, including delivery to the final consumer.

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[20] "Last Chance?" *Forbes*, May 30, 1988, p. 63.

The basic nature and number of parts that make up an HDTV set could create additional employment in the durable and non-durable manufacturing sectors. HDTV sets will be manufactured with more and more sophisticated parts -- from advanced electronic memory chips and CD-quality sound systems to plastic knobs and coated wire -- than color TVs made today. In addition, more workers could be employed in upstream raw materials production and in providing the services consumed by the primary pipeline activities. For example, larger sets require more packaging materials and larger cardboard boxes, increasing requirements from the paper and plastics industries and, in turn, more raw materials from the basic extraction and forestry industries; more transportation services would be required for the movement of the product to the market, increasing consumption of fuel at the pump and services in the maintenance and repair of transportation equipment. These examples of derived demand, and many others that could be postulated, would result in additional employment in the HDTV pipeline compared with the workforce employed in the production and distribution of domestically manufactured color TVs today.

Employment adjustments required by the physical characteristics of HDTVs, taking into account that not all the sets projected to be produced in the year 2003 will be in the 30-inch and larger screen sizes, are as follows:

- Receiver set, picture tube, furniture cabinetry, and other manufacturing industries -- 5 percent increase in employment, or 2,800 workers in total
- Retail trade -- 7.5 percent increase in employment, adding 2,300 workers
- Wholesale trade and services -- 10 percent increase, or 2,700 additional workers
- Transportation, communication, utilities, and all other industries -- 15 percent increase in employment, adding 1,100 workers

Combining these potential employment adjustments means that an additional 10,200 workers may be added to the adjusted baseline employment figure of 118,600 to arrive at the number of workers who might be employed in the TV pipeline for HDTV. In total, 128,800 workers may be employed in the year 2003 in the manufacturing of U.S.-made HDTV receivers.

Net Employment Impact

Employment in the U.S. TV pipeline will be the same in the year 2003 whether or not HDTV is introduced into the U.S. consumer electronics market. In 2003, about 275,000 workers will be employed in the TV production chain, manufacturing and distributing U.S.-made color TVs or in support of production and sales activities. The number of workers employed in the TV pipeline depends on the volume of production, product mix, and sources of inputs. Compensating differences in these factors suggest that HDTV will have no net employment impact on the pipeline.

Estimates of U.S. sales and production of color TVs in 1987 and in 2003 for both the HDTV and "without HDTV" (if HDTVs were not produced and marketed in the United States) scenarios are set out in Table IV-7. Both scenarios are based on the same forecast of sales. HDTV will be introduced initially at the high end of a varied product line that is differentiated primarily on the basis of screen size and model type (table and portable, or con sole and combination). HDTV's impact on color TV sales will be reflected in the mix of screen sizes and the value of production rather than in the total number of sets produced and sold.

In 2003, almost half of the TVs produced in the United States would be in the 26-inch and larger screen size if HDTV did not enter the market. The high initial price of the 30-inch and larger screen HDTV will divert some

Table IV-7. U.S. Sales and U.S. Production of Color TVs, by Screen Size, 1988 through 2003

	Screen size (inches)				
Year/scenario	12 and smaller	13 - 19	20 - 25	26 and larger (a)	Total
	millions of units				
1987					
Unit sales	1.3	9.8	5.2	3.4	19.6
Production	0.0	5.4	4.6	3.4	13.4
2003: HDTV scenario					
Unit sales	5.6	13.3	11.3	10.1	40.2
Production					
HDTV sets	0.0	0.0	2.0	10.1	12.1
NTSC sets	0.0	6.7	8.2	0.0	14.9
Total	0.0	6.7	10.3	10.1	27.0
2003: Non HDTV scenario					
Unit sales	5.6	13.3	7.8	13.5	40.2
Production	0.0	6.7	7.8	13.5	28.0
	percent distribution				
1987					
Unit sales	6.4	49.9	26.5	17.2	100.0
Production	0.0	40.3	34.3	25.4	100.0
2003: HDTV scenario					
Unit sales	13.9	33.1	28.1	25.0	100.0
Production					
HDTV sets	0.0	0.0	16.7	83.3	100.0
NTSC sets	0.0	44.7	55.3	0.0	100.0
Total	0.0	24.7	38.1	37.3	100.0
2003: Non HDTV scenario					
Unit sales	13.9	33.1	19.4	33.6	100.0
Production	0.0	23.8	27.9	48.3	100.0

Note: Totals may not sum due to rounding.

a. Includes only sets 30 inches and larger in the HDTV scenario.

Source: RRNA.

would-be buyers of large screen TVs to purchase a smaller, 20- to 25-inch NTSC set. Once HDTV is introduced in the smaller 20- to 25-inch screen size, increases in the sale of 30-inch and larger sets will abate; the slack will be absorbed by sales of the new smaller and less expensive models. The forecast indicates that with HDTV, the 20- to 25-inch screen share will be about the same as the share of 26-inch and larger sets, somewhat less than 40 percent each. The 26-inch and larger segment of the market has been growing strongly and, as illustrated in Figure IV-2, has the potential to reach 35 percent of U.S. sales if current trends continue. In the market scenario without HDTV, almost one-half of the sets produced in the United States would be in the large screen sets while 20- to 25-inch sets would make up only 28 percent of production. If it takes more workers to produce larger TVs than to produce smaller TVs, fewer workers in total would be employed in the TV pipeline in 2003 if HDTV is commercialized than would be without HDTV.

Differences in input sourcing under the two scenarios also have employment implications. On average, somewhat less than 90 percent (89.5 percent) of the value of a U.S.-produced color TV, measured by its retail price, is contributed or added from domestic sources; with the change in product mix, in 2003 the average domestic content of a U.S.-made color TV will be about 91 percent. Although this difference is small, it will have some measurable impact on indirect employment (industries upstream in the production chain). The employment implications of the differences in domestic content are attenuated, however, by the shift in product mix: a higher share of TVs in the 20- to 25-inch screen sizes will occur with HDTV than would occur without HDTV.

A few rough calculations help to demonstrate the impact of HDTV in employment in the TV pipeline. About 128,800 workers will be employed producing the 12.1 million HDTV sets that will be made in the United States in 2003. In addition to HDTVs, U.S. manufacturing plants will produce

14.9 million NTSC sets in the 13- to 19-inch and the 20- to 25-inch screen sizes. In 1987, nearly 132,000 workers were employed in the production of 13.4 million sets or about 9,800 workers for every million TVs. Therefore, on a simple proportional basis, the 14.9 million NTSC sets that are projected to be produced in 2003 will create employment for about 146,000 workers. If the difference between the domestic content of production in 1987 and in 2003 (89.5 percent and 91 percent, respectively) balances the smaller size of the average set, total employment will be about 275,000.

In 2003 without HDTV, 28 million TV sets would be produced in the United States, more than two times the production of 13.4 million sets in 1987. At 9,800 workers per million sets produced, the 28-million unit forecast implies employment of 274,400 workers. If the differences between 1987 and 2003 production in domestic content and product mix compensate for one another, then employment would be about the same (275,000) as the number approximated for the HDTV scenario.[21] These estimates indicate that in the long run HDTV will not result in increased employment in the TV pipeline.[22]

Contributions of HDTV to the U.S. Economy

The U.S. HDTV production chain has a potential to add $16.3 billion to the economy and employ about 129,000 workers -- contributions reflecting only the direct and indirect impacts of the new technology on the TV pipeline. In addition to these initial impacts, between $6.5 and $8.0 billion in value added will be created in 2003, as will employment for an additional 103,000 workers in the economy. These induced contributions reflect the goods and services purchased by workers whose employment depends on the production and sale of the product. The total contribution of HDTV has a potential value of at least $23 billion and potential employment of 232,000 workers. The U.S. color TV pipeline, however, would have the same induced impacts without HDTV.

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[21] Different screen size mix scenarios would yield different net employment impacts.

[22] As noted earlier, employment in the short run is likely to increase in response to the increased research, development, and engineering efforts needed to bring HDTV to the market. The continuing implications of these activities, their secondary benefits, and by-products could permanently add to employment in related industries.

The net impact of HDTV on the U.S. economy is a $6.2 billion increase in GNP. Total employment attributable to TV manufacturing will be 495,000. The same number would be employed because of the manufacturing of TV sets, however, if HDTV were not introduced into the U.S. consumer electronics market.

The potential benefits of HDTV for the U.S. economy are not limited to the impacts associated with the TV receiver set industry. Substantial opportunities will be created in transmission equipment and communications delivery systems with the establishment of an HDTV transmission standard.

Economic Contribution of HDTV
Employment and Value Added

RRNA's assessment of the economic contributions of the color TV manufacturing industry in 1987[23] provides a basis for estimating the potential economy-wide induced impacts of HDTV (see Table IV-8). In 1987, 180 workers were employed in the economy for every 100 workers in the TV pipeline. This ratio implies that the 128,800 workers estimated to be employed in the HDTV production chain in 2003 will support the employment of 103,000 additional workers. The commercialization of HDTV sets in the United States will create employment opportunities for a total of 232,000 workers.

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[23] Reported in Chapter III.

Table IV-8. Summary of the Contribution of the TV Receiver Set Manufacturing Industry to the U.S. Economy, 1987

Contribution	Employment (thousands)	Value added (billion dollars)
Direct and indirect	131.7	5.017
Induced	105.4	3.837
Total	237.0	8.853

Note: Totals do not sum due to rounding.
Source: Table III-5 and Table III-6.

The 237,000 workers employed in the U.S. economy because of the TV pipeline in 1987 purchased products and services valued at $3.8 billion to the economy, an average of $16,200 per worker. If prices of consumer goods and services increase, on average, 3.5 percent per year during the forecast period, then the $16,200 in induced value added per worker in 1987 will be worth $28,100 in 2003. The 232,000 workers who will be employed in the production and sale of HDTVs will purchase goods and services with a value to the U.S. economy of $6.5 billion (in 2003 dollars). With the addition of the $16.3 billion that will be created by the HDTV pipeline, the manufacturing and sale of HDTVs in the United States has the potential to contribute almost $23 (22.8) billion to GNP.

Twenty-three billion dollars may be a conservative estimate of the potential contribution of HDTV to the U.S. economy. An additional $1.5 billion can be contributed by the HDTV production chain if as much as one-half the foreign content of the 12.1 million sets projected to be produced in the

United States were supplied from domestic sources. The competitive advantages of the U.S. custom-made computer chip industry and the additional indirect impacts on supporting industries upstream in the pipeline could account for this additional indirect added value. The potential contribution of HDTV, then, will be $24.3 billion.[24]

As summarized in Figure IV-4, HDTV has the potential to create employment for 232,000 workers and to contribute at least $22.8 billion to the U.S. economy. Almost 72 percent of the total value added will be contributed by the HDTV production and distribution chain employing 129,000 workers, 56 percent of the total number of workers who will be employed because of the commercialization of HDTV in the United States.

Since the same number of workers can be expected to be employed in the U.S. TV pipeline in 2003 whether or not HDTV is commercialized, the induced contributions in employment and value added will be the same under either scenario. Summary figures are presented in Table IV-9. Induced employment of 220,000 workers and GNP contribution of $13.9 billion are the same for each scenario. Almost 500,000 workers will be employed in the economy because of TV production and distribution whether or not HDTV is commercialized. If HDTV were not brought to the market, the manufacturing of TVs would contribute $28.8 billion to GNP; with HDTV, TV manufacturing will add $35 billion to GNP. The net impact of HDTV on the U.S. economy is, therefore, a $6.2 billion increase in GNP contributed directly and indirectly by the TV pipeline. This represents a 21.5 percent increase in the total (direct, indirect, and induced) contribution of TV manufacturing in the United States to GNP.

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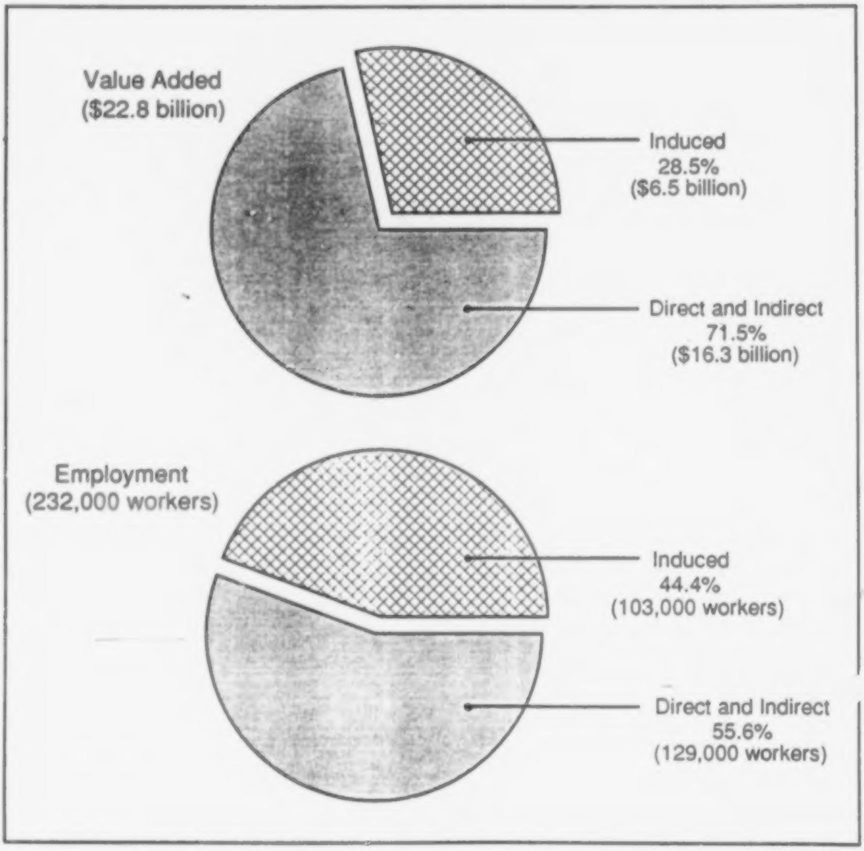
24. The distribution and retailing of imported HDTVs will also contribute to the U.S. economy.

Figure IV-4. Potential Contribution of HDTV Receiver Set Manufacturing to the U.S. Economy, 2003 (a)



a. These estimates are based on the continuation of production economies and technologies present in 1987. Induced value added is measured in 2003 dollars.

Source: RRNA.

Table IV-9. Economic Contributions of TV Manufacturing in the United States, 2003

Contribution	U.S. production with HDTV						U.S. production without HDTV	
	Value added (dollars)			Employment			Value added (dollars)	Employment
	HDTV	NTSC	Total	HDTV	NTSC	Total		
	---------- billions ----------						----- billions -----	
Direct and Indirect	16.3	4.8	21.1	129,000	146,000	275,000	14.9	275,000
Induced	6.5	7.4	13.9	103,000	117,000	220,000	13.9	220,000
Total	22.8	12.2	35.0	232,000	263,000	495,000	28.8	495,000

Note: Direct and indirect employment contributions are dependent on the product mix and production location assumptions used in this analysis.

Source: RRNA.

Additional Benefits of HDTV for the U.S. Economy

The potential benefits of HDTV are greater than those estimated for the TV receiver set industry alone. A TV set is a device for receiving and reproducing broadcast programs and for displaying electronically recorded material for the viewer's use. TVs are used for entertainment, education, communication, and other purposes. Virtually every activity with an economic dimension associated with producing, transmitting, and using the content of a television transmission or display has the potential to be affected by HDTV. These activities include complementary products and services -- for example, cable TV, VCRs, and their software -- and communications transmission and delivery systems.

Although many far-reaching developments and secondary benefits could and undoubtedly will arise from HDTV, the most apparent and significant short-term benefits will come from the replacement of the nation's stock of transmission equipment -- commercial/terrestrial broadcasting, satellite communications, and cablecasting -- as well as related delivery systems, like fiber optics, and many types of electronic equipment. The production and sale of program production equipment, programming and other software, and complementary products (e.g., VCRs) would take place even if HDTV were not commercialized in the United States.

Conclusion

HDTV is the next step in the evolution of the television. This new technology will have a substantial impact on the U.S. TV pipeline. Nearly every home in America has a television -- HDTV will transform TV viewing as we know it today.

APPENDIX A. ECONOMIC IMPACT OF COLOR TV MANUFACTURING: DETAILED DATA

Table A-1. Contributions of U.S. Color TV Manufacturing, by Industry, 1980, 1985, and 1987

Industry	Output			Value added			Employment		
	1980	1985	1987	1980	1985	1987	1980	1985	1987
	----- billion dollars -----			----- billion dollars -----			---- thousands ----		
Raw materials (a)	.423	.544	.545	.222	.283	.283	3.5	4.5	4.6
Construction	.179	.223	.222	.098	.123	.122	3.3	4.1	4.1
Manufacturing									
Picture tubes	.608	.640	.683	.304	.319	.341	9.1	9.7	10.2
Electronic components and parts	.076	.066	.068	.038	.033	.034	1.1	1.0	1.0
Furniture cabinetry	.214	.300	.299	.092	.128	.127	4.0	5.7	5.7
Color TV receivers	3.692	4.589	4.258	1.105	1.844	1.741	23.2	29.5	28.1
Other durable	1.302	1.590	1.572	.526	.639	.631	12.4	15.1	14.9
Non-durable	1.916	2.418	2.401	.616	.773	.765	13.9	17.6	17.5
Wholesale trade	1.436	1.206	1.162	.784	.656	.631	21.7	18.3	17.6
Retail trade	1.530	1.887	1.797	.823	1.015	.963	50.2	61.6	58.5
Advertising	.343	.403	.387	.208	.245	.235	8.9	10.5	10.2
Finance, insurance, and real estate	1.371	1.766	1.765	.925	1.192	1.192	8.7	11.3	11.2
Services, other	1.051	1.368	1.368	.617	.803	.803	24.4	32.3	32.2
Transportation	.404	.490	.479	.224	.271	.265	5.3	6.4	6.2
Communications and utilities	.576	.706	.701	.321	.392	.388	4.1	4.9	4.9
All other	.259	.363	.361	.234	.332	.332	6.5	10.0	10.0
Total	15.380	18.560	18.069	7.136	9.048	8.853	200.3	242.5	237.0

Note: Items may not sum to totals due to rounding.

a. Includes agriculture, forestry, fishing, and mining.

Source: RRNA.

A-2

Table A-2. Contributions of U.S. Color TV Manufacturing, by Census Region, Geographic Division, and State, 1987

Census region, geographic division, and state	Value added (billion dollars)	Percent distribution	Employment (thousands)	Percent distribution
North East	1.396	15.8	42.7	18.0
New England	.284	3.2	9.5	4.0
Connecticut	.082	0.9	2.7	1.1
Maine	.017	0.2	.6	0.2
Massachusetts	.133	1.5	4.5	1.9
New Hampshire	.013	0.1	.5	0.2
Rhode Island	.018	0.2	.6	0.3
Vermont	.021	0.2	.7	0.3
Middle Atlantic	1.112	12.6	33.2	14.0
New Jersey	.325	3.7	10.0	4.2
New York	.465	5.3	13.3	5.6
Pennsylvania	.322	3.6	10.0	4.2
North Central	3.026	34.2	77.3	32.6
East North Central	2.270	25.6	57.5	24.3
Illinois	.587	6.6	15.0	6.3
Indiana	1.093	12.3	24.8	10.5
Michigan	.193	2.2	6.0	2.5
Ohio	.299	3.4	8.7	3.7
Wisconsin	.098	1.1	3.0	1.3
West North Central	.756	8.5	19.7	8.3
Iowa	.065	0.7	1.8	0.8
Kansas	.053	0.6	1.5	0.6
Minnesota	.089	1.0	2.9	1.2
Missouri	.501	5.7	12.1	5.1
Nebraska	.031	0.4	.9	0.4
North Dakota	.009	0.1	.2	0.1
South Dakota	.008	0.1	.2	0.1

(continued)

Table A-2 Continued.

Census region, geographic division, and state	Value added (billion dollars)	Percent distribution	Employment (thousands)	Percent distribution
South	2.931	33.1	77.5	32.7
South Atlantic	.893	10.1	28.9	12.2
Delaware	.011	0.1	.5	0.2
Florida	.203	2.3	7.2	3.0
Georgia	.210	2.4	5.6	2.4
Maryland	.067	0.8	2.2	0.9
North Carolina	.181	2.0	6.4	2.7
South Carolina	.063	0.7	2.2	0.9
Virginia	.098	1.1	3.2	1.4
Washington, D.C.	.023	0.3	.7	0.3
West Virginia	.037	0.4	.9	0.4
East South Central	1.269	14.3	30.3	12.8
Alabama	.139	1.6	3.7	1.5
Kentucky	.087	1.0	2.4	1.0
Mississippi	.041	0.5	1.3	0.6
Tennessee	1.002	11.3	23.0	9.7
West South Central	.769	8.7	18.2	7.7
Arkansas	.237	2.7	5.5	2.3
Louisiana	.110	1.2	2.0	0.9
Oklahoma	.059	0.7	1.7	0.7
Texas	.363	4.1	9.1	3.8
West	1.501	17.0	39.6	16.7
Mountain	.206	2.3	6.2	2.6
Arizona	.058	0.7	2.0	0.8
Colorado	.057	0.6	1.8	0.7
Idaho	.013	0.1	.4	0.2
Montana	.013	0.1	.3	0.1
Nevada	.016	0.2	.5	0.2
New Mexico	.022	0.2	.5	0.2
Utah	.020	0.2	.6	0.3
Wyoming	.007	0.1	.2	0.1
Pacific	1.295	14.6	33.4	14.1
Alaska	.012	0.1	.2	0.1
California	1.158	13.1	29.5	12.5
Hawaii	.016	0.2	.5	0.2
Oregon	.039	0.4	1.1	0.5
Washington	.070	0.8	2.0	0.8
Total	8.853	100.0	237.0	100.0

a. Items may not sum to totals due to rounding.

Source: RRNA.

APPENDIX B. HDTV FORECAST: DETAILED RESULTS

Table B-1. Forecast of Color TV and HDTV Unit Sales, Retail Value, U.S. Production, Retail Value of U.S. Production, and Value Added by U.S. Production, 1989 - 2003

(Units in millions and dollars in billions)

	Unit sales			Retail value			U.S. production			Retail value of U.S. production			Value added by U.S. production		
		HDTV			HDTV			HDTV			HDTV			HDTV	
Year	Total (units)	Number (units)	Percent of total	Total (dollars)	Amount (dollars)	Percent of total	Total (units)	Number (units)	Percent of total	Total (dollars)	Amount (dollars)	Percent of total	Total (dollars)	Amount (dollars)	Percent of total
	(1)	(2)	(3)=(2)/(1)	(7)	(8)	(9)=(8)/(7)	(4)	(5)	(6)=(5)/(4)	(10)	(11)	(12)=(11)/(10)	(13)	(14)	(15)=(14)/(13)
1989	21.3	0	0.0	9.9	0.0	0.0	14.6	0	0.0	8.0	0.0	0.0	7.1	0.0	0.0
1990	22.4	0	0.0	10.6	0.0	0.0	15.3	0	0.0	8.7	0.0	0.0	7.6	0.0	0.0
1991	23.6	0	0.0	11.3	0.0	0.0	16.1	0	0.0	9.3	0.0	0.0	8.2	0.0	0.0
1992	24.8	0	0.0	12.0	0.0	0.0	17.0	0	0.0	9.9	0.0	0.0	8.7	0.0	0.0
1993	26.0	0.7	2.5	13.9	1.6	11.7	17.8	0.7	3.6	11.8	1.6	13.8	10.3	1.4	13.4
1994	27.3	1.6	6.0	15.7	3.6	23.2	18.7	1.6	8.8	13.5	3.6	27.0	11.7	3.1	26.4
1995	28.6	3.3	11.7	18.1	7.1	39.0	19.5	3.3	17.1	15.8	7.1	44.6	13.7	6.0	43.8
1996	29.9	4.8	15.9	19.8	9.7	48.9	20.5	4.8	23.2	17.5	9.7	55.5	15.1	8.2	54.5
1997	31.3	6.5	20.8	21.8	12.9	58.9	21.4	6.5	30.3	19.4	12.9	66.4	16.8	10.9	65.2
1998	32.7	8.5	26.0	23.8	16.3	68.6	22.4	8.5	37.9	21.3	16.3	76.7	18.4	13.9	75.4
1999	34.1	9.5	27.9	24.8	17.2	69.6	23.3	9.4	40.2	22.1	17.1	77.7	19.1	14.6	76.5
2000	35.6	10.4	29.2	26.2	18.5	70.8	24.4	10.2	41.8	23.4	18.4	78.7	20.2	15.7	77.5
2001	37.1	11.3	30.5	26.0	18.2	70.1	25.0	10.6	42.5	22.9	17.9	78.0	19.8	15.2	76.8
2002	38.6	12.2	31.5	26.9	19.0	70.6	26.0	11.3	43.6	23.7	18.6	78.4	20.4	15.8	77.3
2003	40.2	13.1	32.5	27.7	19.7	71.1	27.0	12.1	44.8	24.4	19.2	78.8	21.1	16.3	77.6

Source: RRNA.

Table B-2. Forecast of Color TV Unit Sales, Retail Value, and Value Added by U.S. Production, "Without HDTV" Scenario, 1989 through 2003

	Unit sales		Retail value		Value added
Year	Total (units)	U.S. production (units)	Total (dollars)	U.S. production (dollars)	by U.S. production (a) (dollars)
	---- millions ----		------------ billions	------------	
1989	21.3	14.6	9.9	8.1	7.1
1990	22.4	15.3	10.7	8.8	7.7
1991	23.6	16.1	11.4	9.5	8.3
1992	24.8	17.0	12.2	10.1	8.8
1993	26.0	17.8	12.9	10.8	9.4
1994	27.3	18.7	13.6	11.4	9.9
1995	28.6	19.5	14.3	12.0	10.4
1996	29.9	20.5	15.0	12.6	11.0
1997	31.3	21.4	15.7	13.2	11.5
1998	32.7	22.4	16.4	13.9	12.1
1999	34.1	23.4	17.1	14.5	12.6
2000	35.6	24.6	17.9	15.3	13.3
2001	37.1	25.7	18.6	15.9	13.8
2002	38.6	26.8	19.3	16.5	14.3
2003	40.2	28.0	20.0	17.2	14.9

a. Value added by U.S. production reflects a foreign content differential across screen sizes.

Source: RRNA.

ECONOMIC POTENTIAL OF ADVANCED TELEVISION PRODUCTS

Report by
Larry F. Darby
Darby Associates
for
National Telecommunications and
Information Administration

7 April 1988

NTIA

Technical
Information
Advisory

Embargoed until Tuesday, 4/12/88
1:00 p.m. EDST Contact: R.T. Gregg
(202-377-[illegible])
1304

REPORT RELEASED BY NTIA FORECASTS MAJOR ATV MARKET

Assistant Commerce Secretary Alfred C. Sikes, head of the National Telecommunications and Information Administration (NTIA), today at the National Association of Broadcasters annual convention in Las Vegas released a report on advanced television (ATV). The report is the first comprehensive economic assessment regarding this new technology, and estimates total potential U.S. sales of ATV equipment exceeding $150 billion by the first decade of the 21st century.

Prepared by Dr. Larry F. Darby, formerly vice president with the New York investment firm of Shearson-Lehman Bros.-Hutton and chief of the Federal Communications Commission's (FCC) Common Carrier Bureau, the ATV report is based on an extensive analysis of the economics and commercial dynamics of both the consumer electronics and semiconductors industries.

"The report for the first time quantifies what's at stake here," Assistant Secretary Sikes stated. "It shows how what our own and foreign governments decide to do will have significant effect on the ultimate distribution of world technological, economic, and political power created by an entire 'family' of high technologies." "It also shows what an important factor consumer-electronics demand is on the semiconductor industry. If U.S. industry fails to be a key participant in ATV technologies, the future strength of the U.S. semiconductor industry will be imperiled."

Major findings of the NTIA commissioned report:

- Significant Future Demand. Demand for advanced television products should be comparable to that for color television and home video cassette recorders, and grow exponentially over the next 20 years.

EXECUTIVE SUMMARY

The television receiver has been one of the few constants in American life in the post-war period. To be sure, citizens have enjoyed the transition from monochrome to color pictures, the addition of alternative program and signal sources, and the option to alter program schedules through recording devices. But the "box"? Some bigger; some smaller; some thinner; some with remote control, stereo sound or a hint of intelligence variously applied. All in all, not much change.

This remarkable stability is about to yield, however, to the forces of digital technologies and market economics which have literally revolutionized so many other aspects of US industry, commerce and consumer welfare.

Research and development groups in several countries have been working for several years to devise and test systems and equipment embodying state-of-the-art integrated circuit technologies to be used in the production, distribution and display of dramatically improved television picture and sound quality. The results to date are impressive. Theater quality images and sound are obtainable from television receivers utilizing these new technologies. Receiver prototypes have been demonstrated under real world conditions and production models are scheduled to be made available to US consumers in the next two to three years.

This paper reports the results of an exploration of the market and public policy implications of the imminent introduction of a range of products which incorporate advanced television (ATV) technologies. The major purpose has been to identify and, where possible, indicate the potential magnitude of the principal economic impacts of the technology. After reviewing market histories of electronics products generally and selected consumer electronic products more intensively, the paper constructs two ATV consumer product growth scenarios. These scenarios characterize potential ATV consumer product diffusion, driven first by a set of pessimistic assumptions about consumer preferences and the economic environment and, secondly, by more optimistic assumptions which result in ATV product diffusion that more or less mirrors the growth paths of successful new consumer electronics products in the United States.

If the growth path of ATV receivers and VCRs traces the historical sales tracks of conventional color television receivers, videocassette recorders, home computers and television receive-only antennas, the new products will achieve one percent household penetration about ten years from now. Applying subsequent growth rates representative of those achieved by their [illegible] 70% [illegible]

★ predecessors indicates that household penetration of the new products may reach 25% in about fifteen years and in twenty years may exceed 70% household penetration. Valuing these unit sales using high and low pricing scenarios yields cumulative market valuation ranges ten, fifteen and twenty years out of $1.7 to $3.5 billion, $26 to $52 billion, and $72 to $144 billion.

Any product market valuation is sensitive to several economic and other forces which may or may not materialize in the next twenty years. Rather than attempting to forecast those forces, the analysis attempts to identify them and to indicate clearly the nature of the sensitivity to them of the calculated scenario values. The algorithm of the calculated scenarios is detailed so that different values, based on different assumptions, can be readily calculated.

Based on the scenario values of primary ATV market development, the analysis explores selected other secondary or indirect economic and market impacts induced by US household adoption of ATV products. Drawing on the results of previous studies of the economic role of electronics industries in the domestic economy, the analysis identifies potential multiplier effects on national income, employment, the balance of trade and the Federal budget.

The total effect on national income of ATV product penetration is the sum of direct and induced economic effects. The scenarios indicate the potential direct economic effects, but "multiplier" effects rippling throughout the economy may yield total economic activity two to three times the level suggested by the scenarios. Utilizing a previously estimated average for value-added per worker in the electronic industries suggests that over 100,000 US jobs may be at stake by the turn of the century.

The scenarios for potential diffusion of ATV related products also implicate immense potential impacts on both the balance of trade and the federal budget. Substantial participation by US manufacturers in the ATV product market may lead to significant contributions toward restoring balance in the twin deficits.

Based on a review of major studies of the causes and consequences of the decline of US leadership in electronics industries generally, and semiconductors more specifically, the paper concludes that imminent developments in markets for ATV products will create both enormous opportunity and risk for US firms and the national interest. Consequently, government policies influencing private sector incentives in developing these technologies are ripe for comprehensive review for consistency with the long term national interest.

TABLE OF CONTENTS

EXECUTIVE SUMMARY. . . . .

I. Introduction. 1

II. Overview of the Market for Electronics Products. 2

- A. Introduction 2
- B. The Consumer Electronics Market. 2
- C. Advanced Television Technology and Systems 4
- D. Basic Determinants of Market Development 7
  - 1. Product Availability 7
  - 2. FCC Docket MM 87-268 8
  - 3. Product Costs/Prices 8
  - 4. Product Demand 11
- E. The Global Market--A Simple Taxonomy 12

III. US Market for Selected Consumer Electronics Products. . 13

- A. Introduction 13
- B. Methodology. 14
  - 1. Stages of New Product Diffusion 14
  - 2. Growth Path for ATV Consumer Products 15
- C. Stage 1--The Innovation Stage. 16
  - 1. Color Television Receivers. 17
  - 2. Videocassette Recorders 18
  - 3. Television Receive-Only Earth Stations. 18
  - 4. Projection Television Receivers 19
  - 5. Home Computers 19
  - 6. Audio Component Systems 20
  - 7. Summary 21
- D. Stage 2--Imitation and Growth. 22
  - 1. Color Television Receivers. 23
  - 2. Videocassette Recorders 26
  - 3. Home Computers. 27
  - 4. Audio Component Systems 28
  - 5. Summary and Synthesis 28

IV. Advanced Television Product Growth Scenarios 30

- A. Scenario 1--Sluggish Penetration 31
- B. Scenario 2--Rapid Product Diffusion. 32
  - 1. Receiver Growth Scenario. 33
  - 2. VCR Growth Scenario 34
  - 3. Market Value of Combined Growth Scenarios . . . 36
- C. Commercial, Industrial, and Government Applications. 39
- D. Other Economic Effects of ATV Diffusion 41
  - 1. Employment Effects 42
  - 2. Multiplier Effects 42
  - 3. Fiscal and Trade Impacts 44
- E. The Market Outside the US 45
  - 1. Western Europe. 45
  - 2. Japan 47

V. Implications for the Microelectronics Industry. 47

VI. Conclusion 51

NOTES. . . . .

APPENDIX A . . . .

I. INTRODUCTION

Dramatic improvements in the visual and sound quality of television receivers and complementary devices are both technologically feasible and imminent. These technological improvements will in the next few years appear in a variety of video-related, commercial and consumer electronics products.

The question is not whether improved television and related products will be introduced to US consumers, but when, and in what form. More fundamentally, from the point of view of the national interest, the question is how and to what extent US industry, by sector and in the aggregate, will participate in what some believe will be a multibillion dollar market late in the next decade. Even if popular estimates of the potential market values involved err by a full order of magnitude, there is still both enormous opportunity and downside risk with respect to the long term national interest.

There is a spirited race underway to define the technical ground rules which will govern the market and its distribution among several high-powered contenders. The race is being contested in laboratories, within domestic and international standards setting bodies, within regulatory arenas and within government and regional planning bodies. The race has only barely begun in the marketplace. But in a larger sense, that may not matter, since administrative and political forces which are now shaping the technical rules of the game will ultimately have enormous influence on the identity of the economic winners and losers.

The technical standards governing the distribution of video programming over the air have been remarkably resilient. The basic transmission standards were first established in 1941 and later refined by the National Television Standards Committee (NTSC). The NTSC system has been able to accommodate the transition from black and white film to color video, as well as audio enhancements from monophonic to stereophonic sound. These improvements have been possible within the technical parameters first established almost fifty years ago, using the six megahertz channels originally allocated and without negative impact on the utility of the installed base of television receivers.

While other improvements in video quality are certainly possible within the NTSC constraints, the next major innovation may well require changes in channel capacity or receiver design, or both. Whether and, if so, how to change the NTSC standards is one of the fundamental issues being debated. Resolution of that issue is given some urgency by the possibility that _de facto_ standards not clearly subservient to the national interest may be established by default. The precipitant cause of this concern is the imminent introduction of significantly improved television products embodying technologies developed abroad. These technologies are generally incompatible with the NTSC standard.

Most observers agree that several forms of improved definition television will be introduced in the US over the next decade and beyond. There are, however, enormous implications of different ways of getting from here to there. The transition from NTSC driven video to the next generation of video products and services might take several paths and proceed rapidly or slowly. There are immense economic stakes riding on the nature of the transition. Both the magnitude of economic activity and its distribution among international and US industry contenders will be determined by the direction and pace of the transition.

The purposes of this report are to analyze some potential economic impacts of the introduction of new video and related products into the US market and to assess in a preliminary way the implications for US economic development and other national goals. The overriding purpose is to set forth reasonable views of the market implications of advanced television (ATV) technologies, systems and products.

II. THE MARKET ENVIRONMENT FOR ATV PRODUCTS

A. INTRODUCTION

This section is intended to provide technological, economic and regulatory context within which ATV product markets will develop. It concludes with a broad scheme for classifying the economic impacts of the adoption and diffusion of new television technologies.

B. THE US CONSUMER ELECTRONICS MARKET

Though ATV has no economic history, it is in a class of products and services, electronics and consumer electronics more specifically, about which we know quite a lot. Electronics constitute the technology of the post-war period and now represent the nation's largest industry--surpassing in sales the auto, chemical and steel industries. Over the last decade electronics industries in the aggregate posted compounded annual growth rates (CAGR) in excess of 13 percent. Consumer electronics growth surpassed even that rate.

By 1986 total sales of consumer electronics products in the US were nearly $29 billion. This represents compound annual growth over the previous decade of about 15%. The consumer electronics market in 1986 was roughly equally divided among four broad classes of products: television receivers, audio receiving equipment, video recording and playing apparatus, and assorted other related products--home computers and software, telephones and answering devices, receive-only earth stations, video game software and cartridges. Table 1 indicates some characteristics of the growth of consumer electronics products over the past decade.

TABLE 1
Factory Sales of Consumer Electronics Products
United States, 1976 - 1986
($ Million)

Product Line	1976	1981	1986
Monochrome TV Receivers	495	505	328
Color TV Receivers	2,755	4,349	6,024
Projection TV		287	529
Video Cassette Recorders	65	1,127	5,258
Color Cameras		147	59
Video Disc Players		55	45
Audio Systems	489	720	1,370
Separate Audio Components	1,027	1,363	1,358
Home Radio	356	501	408
Portable Audio Tape Equipment	1,055	1,157	1,389
Car Audio	497	2,000	2,800
Blank Audio Cassettes		242	304
Blank Video Cassettes			1,480
Other		44	7,369
Total	6,739	12,497	28,721

Source: 1987 Electronic Market Data Book, EIA Marketing Services Department.

About half of the consumer electronics products available today have been introduced in the past ten years. Products proliferate and many fail. Rivals in the marketplace contend with both declining prices and better quality. One can buy a radio today for less than the price of a single vacuum tube seventy years ago. While the consumer price index has roughly tripled over the past twenty years, the prices of popular consumer electronics products (those that have been around that long) have been roughly constant and, in the case of television sets, have actually declined by about twenty percent. (See Table 2.)

TABLE 2
Consumer Price Index:
Selected Products and Years
(1967=100.0)

Year	Radios	Sound Equip*	Tape Recorders	TVs	CPI
1967	100.0		100.0	100.0	100.0
1972	98.9		94.3	99.5	125.3
1977	105.0		95.1	101.7	181.5
1982		113.7		103.9	289.1
1983		111.8		100.3	298.4
1984		108.9		95.3	311.1
1985		105.2		88.6	322.2
1986		102.3		83.1	328.4

Source: U.S. Department of Labor
Note: * A new series, sound equipment, combines radio and tape players from 1980 forward.

In short, the market environment within which new video products will be introduced is our largest, our most innovative, and, in several essential respects, our most dynamic

C. ADVANCED TELEVISION TECHNOLOGY AND SYSTEMS

Despite the obvious durability of the NTSC standards, they are, nevertheless, based on a very limited, some say primitive, set of technologies. Furthermore, the standards were adopted at a time when there was only one available signal or program distribution technology, i.e., terrestrial broadcasting. There are now several distribution media--coaxial cable, satellite distribution, videocassettes and videodiscs, and multipoint microwave distribution systems. The future, no doubt, augers even greater diversity in distribution, including systems relying mainly on optical fiber technologies.

NTSC =
analog

NTSC systems are optimized, more or less, within constraints posed by analog signalling technologies, despite the fact that the world of electronic opportunity is increasingly digital.

Two specific developments, advances in signal processing and storage technologies, deserve mention in this context. Both derive from the development of semiconductors. Chips make it possible and increasingly inexpensive to distribute, process and store information--including digitized visual images. The quality of images captured and transmitted from space, moon walks and "close-ups" of missile sites, for example, suggest the expanding limits of image processing technologies. Digital compression techniques permit more effective use of the radio frequency spectrum in over-the-air transmissions, thereby allowing transmission of more information in the same bandwidth. "Smart" receivers with the ability to store and process video signals are now well within the reach of off-the-shelf semiconductor technologies.

Semiconductor technology has made possible a broad range of multipurpose, multifunctional receiver designs which were scarcely dreamed of at the time the NTSC standards were institutionalized. These new designs will avail users better sound and image quality, but also promise the potential for greater interaction within and among groups of users, receivers and program sources.

Advanced television is a constellation of technologies which combine to make possible several striking improvements in television picture and sound quality when compared to that which is currently available. Visual characteristics comparable to 35 millimeter film quality accompanied by compact disk quality stereo sound have been demonstrated.

A survey of the literature describing various advanced television systems under development yields a richly diverse array of technical improvements.[1] Depending on how one defines a "system", the type of improvements one includes, and when the count is taken, there appear to be about a dozen systems now under development or serious study. The systems vary in several dimensions. Some are channel compatible; some are receiver compatible; and, some are neither.

There is also significant variation among the different systems with respect to receiver complexity, aspect ratios, as well as line, frame and field resolution. System performance can be measured against several technical benchmarks: resolution, lines, frames/second, fields/second, signal to noise ratio and so forth. However, the hedonic performance of the various systems is very much a matter of personal judgment based on personal perceptions and individual preferences.[2]

High Definition Television (HDTV) is the most advanced of a trio of technology clusters, as defined by a classification scheme adopted by the Advanced Television Systems Committee (ATSC). The ATSC taxonomy includes:

- Improved NTSC Systems
- Enhanced 525 Line Systems
- HDTV Systems

Each of these systems improves on one or more of the key visual/aural characteristics of NTSC television: horizontal and vertical resolution as defined by the number of video "lines" in the signal, color fidelity and picture sharpness, the ratio of picture width to picture height (the "aspect" ratio), sound fidelity, motion rendition and others. The visual image is further improved by the elimination of certain "artifacts" or imperfections in image rendition; for example, backward spinning wagon wheels and bluish-red smudges on an American flag.

Improved NTSC Systems By definition, these operate wholly within the current broadcast technical standards. Improvements are made possible by "combing" interspersed signals at both the transmitter and the receiver; by converting to progressive from interlaced scanning through the use of a memory device in the receiver; and, by interspersing more video information throughout the normal six megahertz channel. The combined effect of these and numerous other technical improvements is to double (roughly) the amount of visual information displayed while reducing some of the picture imperfections of traditional systems. These systems are generally compatible with both existing channel allocations and the embedded receiver base.

Enhanced 525 Line Systems These systems could, theoretically at least, incorporate many of the techniques available for upgrading NTSC systems. In addition, through a form of time divided, multiplexed packet transmission, signal quality and information quantity are appreciably enhanced. One such system is now being marketed and used in Australia for satellite transmissions. This and several other systems rely on multiplexed analog components (hence the name MAC). These systems generally require a signal converter to make them compatible with standard receivers. MAC systems generally require more than 6 MHz for transmission. B-MAC can be compressed into a standard channel, albeit with significant degradation of image quality. MAC systems are potentially compatible with other transmission or distribution media--cable, satellite, discs, cassettes, etc. The MAC approach is being developed primarily in Western Europe.

HDTV Systems There are several HDTV systems under development, but the most widely publicized effort in this class is the Japanese Broadcasting System (NHK) family of technologies, systems and products. The result of almost two decades of development, the NHK system is the only one for which supporting products are now available on the market. Studio production equipment manufactured to NHK specifications is now being used in this country and those specifications appear to have become the de facto standard in this country and Canada.

NHK demonstrated a transmission system in 1981. It explores the limits of analog technology and was originally intended for use with direct broadcast satellites. The prototype system required 30 megahertz of bandwidth for transmission, but in 1984 a reduced bandwidth version, called MUSE, was introduced. Transmission of the MUSE format is incompatible with the current 6 megahertz standard. The MUSE signal can be displayed, with some sacrifice in quality, on conventional NTSC sets coupled to a special converter.

Home video equipment embodying the NHK technology, according to NHK representatives, is scheduled to be introduced into this country in 1990 with the planned shipment to US dealers of television receivers, videocassette players and disc players.[3]

D. BASIC DETERMINANTS OF MARKET DEVELOPMENT

Product Availability Despite the inevitability of the introduction of new video products and their eventual widespread acceptance by users, the timing and technical configurations of new products is still very much up in the air. As indicated above, there is wide dispersion among various systems in technical and performance dimensions. But, there is also fairly sobering uncertainty about when different products may actually be made available. Only NHK has announced an initial production schedule. Other systems have not yet been field tested. All are still subject to a bewildering array of technical and economic questions which bear heavily on the rate at which production engineering and product specification can be tailored to comply with user needs and market demand.

Central to the fundamental question of availability is the speed and content of resolution of a complex web of technical, economic, and geopolitical public policy issues related to the conditions for, and the impact of, the introduction of ATV products. Although the Federal Communications Commission (FCC) will provide an important forum for airing the contentions of interest groups, and is obliged by current law to decide questions of television spectrum use, both the Executive Branch and the Congress will very likely play key roles in any final determinations on the pivotal questions.

MM Docket No. 87-268 Responding to a petition filed by terrestrial broadcasting interests, the FCC issued late last year a Notice of Inquiry soliciting views and data on a broad reaching set of questions raised by the different potential applications of ATV technology.[4] The complexity of the issues raised discourages easy generalization or simple summary. However, the breadth, depth and intensity of the subsequent responses by large and diverse economic interests signal unmistakably the magnitude and ubiquity of the stakes involved.

In a nutshell, the FCC is seeking information upon which to base an evaluation of the various costs and benefits to its constituencies of potential changes in the NTSC standards. These costs and benefits have several dimensions.

Several of the ATV proposed systems would require use of additional bandwidth in the frequency spectrum--bandwidth which has valuable alternative uses and which is coveted by several other potential users. Some systems are incompatible with the installed base of NTSC receivers now being used in U.S. homes. Both prices and the performance of new ATV products will be significantly affected by the details of any change in the current NTSC specifications. The list of corporate participants reads like a "Who's Who" of U.S. telecommunications with several new entries--domestic and foreign--rounding out the roster of players with a significant economic or other interest in the content of any new standards and frequency assignments.

The outcome of this proceeding and of processes within the Administration and the Congress will have an inestimable effect on the ultimate character of both the supply and demand for ATV products. Despite the FCC's clear intention and desire to resolve the key issues fully and quickly, the history of similarly momentous FCC proceedings demands its due. The National Telecomunications and Information Administration has suggested that the FCC should declare its intention to establish a broadcast transmission standard during 1991. (See Appendix A.) As a practical matter, we expect that several regulatory questions with significant economic impact on the ATV market may linger well into the next decade.

Production Costs and Prices The principal goal for potential suppliers of HDTV products is to earn a return on total investment which exceeds the cost of capital used up in the process; in short, to make profits. That objective implies that prices in the long run must exceed unit total costs.

Suppliers will have substantial discretion in pricing. Pricing strategies for all emerging industries are complex and there are no hard and fast rules to follow. Differing institutional constraints (product familiarity, expected strategy of rivals and the nature of government imposed technical constraints) render them different for each emerging industry.[5]

The pricing problem is particularly vexing for ATV pioneers. There is almost baffling strategic uncertainty and every reason to believe that different suppliers will adopt different pricing strategies. Successful strategies will be emulated to the extent possible as failing approaches are scrapped. The prospects are for a very dynamic pricing environment.

Historical experience with other emerging industries/product lines and scattered other available information permit us to sketch out the broad characteristics of a general pricing scenario. These general considerations are most helpful in developing the bounds of secular price trends. They are considerably less so in making point estimates of prices for particular products on some particular future date.

Pricing considerations are important to the present analysis for two reasons. Prices will influence the rate of penetration of ATV products and the value of the market which does evolve. Secularly declining prices imply faster product diffusion. Prices are also instrumental in giving signals to suppliers about potential profits in the market, while also providing a benchmark for measuring the economic activity associated with the introduction of the technology.

In the long run, prices will likely settle in the vicinity of unit costs. Entry of new firms and the appearance of new and differentiated products will tend to suppress prices if they appear to be significantly above unit costs. Exit of incumbents and contraction of supply will force prices upward toward cost if it falls below. These are the tendencies in workably competitive markets; and we expect that the ATV market will qualify in this respect.

Each product line that ultimately reaches the end user will be responsible, in principle at least, for covering the costs occasioned to bring it to market. At this point it is not clear what product configurations will emerge. Nevertheless, whatever products materialize will be responsible over the product life cycle for covering the aggregate of three broad classes of costs: sunk costs, fixed costs and variable costs.

Sunk costs are all those expenditures made and obligations incurred prior to commencing production. In the present case, they are, for the most part, the result of expenditures for research, development, and related activities. Every supplier will incur such costs, although not the same amount or over the same time period.

The magnitude of sunk costs incurred to date is not clear, and even less is known about how much will be spent in the future on the various contending systems. Detailed information is held quite closely and public disclosures are not always completely reliable. The financial commitment made to develop the NHK family of technologies and products appears to be well in excess of $500 million to date. The EUREKA HDTV program of the European Community has been funded at 200 million ECUs. Total R&D expenditures to date in the US private sector appear to be on the order of $70 million.[6]

NHK
7 times
U.S. [illegible]

Suppliers have wide latitude in recovering these costs by allocating them over different products in different markets over the life cycle of several product lines. In absolute terms, ATV sunk costs impress as being quite substantial. But, depending on the eventual size and scope of the market for products embodying these technologies, they may on average represent fairly small additions to the delivered price of final products. For example, $200 million spread over the US installed base of TVRO earth stations would lift the cost of an antenna by about $100, or about 5% of its average value. Higher penetration of ATV products, to the extent it occurs, will proportionally reduce the average burden of research and development costs on final product prices.

The real significance of sunk costs [illegible] to recover them through the price structure than in whether they can be recovered at all. This uncertainty constitutes a significant barrier to firms considering entry. Several promising ATV developmental approaches may never overcome this hurdle.

High volume consumer markets can amortize large sunk costs with nominal markups. The problem arises when large markets do not develop. Recognition of this fact leads to an expectation that introductory prices for new ATV products will be designed to permit fairly rapid market penetration and will not reflect much concern for recovering sunk costs in the short run.

The second category of costs, unlike the first, is incurred in the process of commencing and carrying out actual production of finished product. These fixed costs are incurred, in part, prior to actual production and, in part, concurrently with production runs. They are, as the name implies, independent of volume for a plant of given capacity. They will increase as plant capacity is expanded and as more plants are added. Fixed costs bear a strong resemblance to popular notions of "overhead" costs--rent, interest, contractual labor obligations, long term commitments for utilities, and the like. Assuming that ATV products will not require processes substantially different from those being used to produce NTSC compatible products, there should be little change in the relative burden of fixed costs on product prices.

Like sunk costs, the burden of fixed costs on final product prices is sensitive to production volumes that can be absorbed by the end user market. Unlike sunk costs, however, none have yet been incurred. And, they will only be incurred in the main when market signals from users appear to justify building large amounts of productive capacity. Fixed costs per unit can be expected to decline as production economies are realized at higher market penetration rates.

Costs in the third category vary more or less directly with the level of production, once minimum levels of output are attained. Materials costs are a large component, but wages, inventory carrying costs, distribution costs, and those associated with sales and marketing are also important. The limited evidence available indicates that these variable costs will account for about three-quarters of the market price of ATV products. Secular reductions in the average burden of variable costs on product price is likely to draw prices down over time. Technological advances affecting components, product design and production processes are also likely, if history is an adequate guide, to provide for secular decline in average variable costs and a consequent downward pressure on product prices.

Demand In principle, consumer demand for ATV products will depend on price, quality, the quality and price of closely related goods/services (substitutes or complements), buyers' income, and buyers' expectations about each of the foregoing. Although these factors by no means exhaust the considerations underlying individual decisions to purchase, they represent a common core of factors which have been successful in "explaining" aggregate consumer behavior.

In practice, these buyer and product/service characteristics appear to have been quite instrumental in determining the rate at which electronics products embodying new technology have succeeded in the marketplace. For example, sales of radios and monochrome television receivers increased as prices fell, as their quality improved, as the number of broadcast transmitters increased and as signal quality and program diversity improved. The importance of the availability of complementary goods is clear from the pattern of growth of audiocassettes and videocassettes, which have closely tracked the growth of companion player/recorders. Similarly, the demand for home computers has been stimulated by the proliferation of diverse, high quality software, and vice-versa.

Since consumer electronics products may be regarded loosely as leisure goods, as opposed to one of the necessities of life, we would expect sales and penetration to be sensitive to the levels of national income and employment and to the business cycle more generally. Although there are classes of "inferior" goods whose use increases as income declines or expectations turn negative (potatoes, do-it-yourself kits, and used cars are common examples), consumer electronics generally do not qualify. To the contrary, the steady growth in sales of color television receivers, for example, has been interrupted only by general economic recession. Aggregate sales of radio sets and monochrome television receivers have followed the same general pattern. The evidence generally indicates that demand for new ATV products will be very sensitive to income levels and expectations.

The broad principles of market demand have generally found clear expression in other consumer electronics markets; and we will look to them for guidance in making assumptions to provide the basis for our ATV product market development scenarios.

E. THE GLOBAL MARKET--A SIMPLE TAXONOMY OF ECONOMIC EFFECTS

The uncertainties described above will be gradually resolved by time, regulatory and political cycles, and more detailed study of the evolution of this market as events yield more information. Although the character of the market for ATV products will be influenced by the resolution of these uncertainties, for now about all we can do is to note them and be appropriately cautious in developing a view of the future.

The economic activity likely to be generated will take numerous forms. It is helpful to classify this activity into descriptive categories: time, location and type of product or service. Economic activity will not materialize completely or instantaneously; it will not appear and grow at the same rate in different parts of the world or in different geographic submarkets; nor will the impact be realized uniformly across different product/service lines. Both "primary" and "secondary" (i.e., supporting, complementary, or induced) activity will be generated.

Thus, aggregate economic activity generated by the development of ATV products can be visualized in four dimensions: geographic area, sector of end product use, the nature of the activity generated and time. Although the distinctions have a certain intuitive appeal, they are more or less arbitrary and adopted largely for expository and analytical convenience.

The location of economic activity can be divided into four geographic trading areas--the domestic market, our principal Western trading partners, Japan, and the rest of the world. These trading areas represent both potential buyers and potential producers.

Secondly, the market in a particular trading area can usefully be subdivided further into three sectors: households, businesses, and government. For reasons that will shortly become clear, this is a particularly helpful way to think about the market for ATV products, especially in the US.

Next, within trading areas and for each end user product, the economic activity generated can be distinguished according to whether the activity is directly the result of the production of the end product (that is, a primary activity), or an economic activity which is inspired by the production, sale and/or use of the primary product. For example, the diffusion of ATV products will require inputs from upstream industries such as electronic components and the materials for such components. Similarly, the growth of ATV sales may be accompanied by the growth of specialized maintainence, repair and service activities; or, by other types of complementary products, comparable to cassettes and discs using the current generation of technology.

Finally, the market has a time dimension. This requires recognition of the fact that economic activity will begin at different times and grow at different rates in different subsectors.

A full explication of the development of global markets for ATV products over, say, the next twenty years would require examination of 480 data points (20 years times 4 trading areas times 3 user sectors times 2 kinds of economic activity). That is clearly beyond the scope of this paper. Obviously, and fortunately, not every data point has the same expected weight. Moreover, some are likely to be inconsequential from a domestic policy perspective. The likely incidence of economic activity is quite concentrated in this four dimensional matrix for reasons that are discussed further below.

III. THE US MARKET FOR SELECTED CONSUMER ELECTRONIC PRODUCTS

A. INTRODUCTION

The analysis of this and subsequent sections attempts to construct scenarios describing, in a rough sort of way, the boundaries within which the economic activity generated by ATV products can reasonably be expected to fall. Thus, the analysis should be regarded as a description of what could happen, rather than a forecast, projection or prediction of what will happen.

The reasons for being tentative about the future of ATV products are well-grounded in the present and in the past. ATV products have a short but rich technological and geopolitical history. There is no economic history--no data trails--to project; there are no established sets of economic relationships from which to derive a prediction; and, we are not divinely inspired to prophesy. Much of the technology is still in a very early experimental stage; some of the technology is still being developed; and, while there is some product available today, even the most optimistic planners expect a lag of three to five years before product is available to even a modest subset of the potential US consumer market.

In this respect, foretelling the economic activity associated with the application of ATV technologies may be likened somewhat to efforts to foresee the development of private, commercial and defense aviation (and supporting industries) three to four years after the Wright Brothers' successful trials at Kitty Hawk.

B. METHODOLOGY

Since there is no market history of any consequence for ATV products, we are left to infer a potential growth path indirectly from the history of other product innovations. This approach draws comfort from the fact that household penetration rates of new consumer electronics products share common elements with diffusion patterns of innovations more generally.

Stages of New Product Diffusion Casual empiricism confirms that new products, like new processes or ideas, are not universally adopted immediately following their introduction.[7] Unlike hula hoops, most new or substantially improved products are adopted slowly in the beginning, then take off after some critical mass has been reached, only to taper off after a relatively high level of market penetration has been achieved. Some, of course, never take off, but the successful ones commonly follow a "diagonal S" shaped growth path which reflects three distinct stages of growth--the innovation stage, an imitation stage and a period of maturation during which sales flatten, decline or disappear.

The innovation stage embraces the early period after a new product is introduced. The product is new; consumers are not familiar with the product; distribution networks are not fully developed so that the product is not everywhere accessible in the market; a few venturesome buyers experiment; and, the product may be improved or repriced in reaction to early consumer responses. With the passage of time, sales begin to gather momentum fueled from a variety of sources: improved distribution networks, better consumer information about the product, development of supporting products or services and the evolution of a product track record. Of course, many products never escape this stage and die here.

The imitation stage commences when sufficient favorable product information emanates from the market to both buyers and sellers. Consumers have become aware of key product characteristics through contact with pioneering buyers. Alternative suppliers glean valuable information about the potential of the market. New suppliers enter and vie for market share through product differentiation and/or price competition. This stimulates demand and, as sales grow, production costs and prices decline further as a result of economies of scale, learning curve effects and market rivalry.

Eventually the market matures. Firms may drop out of the market or be absorbed by rivals. Prices stabilize. High penetration rates among potential buyers have been achieved and sales to first time buyers begin to yield to replacement sales as the market driver. The product may become standardized and sell pretty much as a commodity. Absent some new stimulus, the market stabilizes with modest or zero growth. New product or process innovations may either rejuvenate the market or sound its death knell.

Growth Path for ATV Consumer Products The cycle described here is by no means universal. It does, however, describe in a very general way some of the important forces that come into play and influence the market development of new products. More to the point, though, we expect consumer ATV products to follow this general pattern, although not necessarily in all its details.

Our method for describing the potential growth path for ATV products will rely on the history of other innovations in consumer electronic products. It goes without saying that markets for ATV products may not follow either the general pattern described above or the pattern for selected consumer electronics described below. These products may suffer the fate of other heralded innovations, like the "picturephone", quadraphonic stereo sound systems, or AM stereo, and not escape stage one. These products may languish like teleconferencing, two-way cable television, videotext or direct satellite broadcasting. Or, the development of the market may be long deferred as a result of regulatory indecision and inaction, as in the case of cellular telephone equipment and services.

While any of these scenarios is quite possible, the special circumstances which led to such dismal market performance are not clearly inherent in these technologies and, it appears, are in several essential respects avoidable. This conclusion, combined with the phenomenal market success of other home entertainment products like color receivers and VCRs impels us to develop the more optimistic scenarios based on more successful product and service lines. At a minimum, the result will be to develop some reasonable upper and lower bounds for the future of ATV market activity. Thus our scenarios may be bounded by two types of errors: underestimating a successful product innovation or grossly overestimating a "dud".

In what follows, we will describe the growth paths traced by selected consumer electronic products for which adequate history and data are available. For each product we will establish the date of its introduction into the consumer market; estimate the length of time required to reach an arbitrarily determined threshold penetration rate (thereby measuring the innovation stage); then, quantify subsequent growth over various time periods as a means of describing subsequent stages of the product cycle.

C. STAGE 1--THE INNOVATION STAGE

We have identified six consumer electronics product lines for which reasonably good data are available and which appear to share some important common characteristics with potential ATV products. These products are: color television receivers, videocassette recorders, "home" computers, television receive-only earth stations (TVROs), large screen/projection televisions and audio stereo component systems. Each of these products was, during the early years of its availability, sold primarily to consumers to be used for home entertainment purposes. Furthermore, each required a substantial consumer outlay as measured by product price as a percentage of family income.

Growth rates based on low initial sales levels are not very meaningful since small incremental growth, measured in dollars, will translate into high relative growth, measured in percentage terms. Thus, in describing the first stage of development of these product lines, it is necessary to establish a benchmark to identify the end point of Stage 1 and the beginning of the next. Selection of this turning point is pretty much a matter of judgment.

After experimenting with different benchmark specifications, calculating the implied subsequent growth path, and comparing the results for consistency, we will use 1% penetration of households as the threshold from which subsequent growth is measured and as the breakpoint between the first two stages.[8] This approach permits the use of physical units of sales, rather than dollar measures, and simplifies the analysis by eliminating the need to account for changes in dollar measures brought about by product price changes, product specification changes, and changes in the value of the dollar.

Color Television Receivers Of the six product lines examined here, color television receivers have the longest, and in many ways, the most interesting history.[9] Color sets were first introduced in 1954 after years under development and discussion of appropriate technical standards. Early growth was modest for a variety of reasons, not the least of which was the paucity of color signals being transmitted by local broadcasters, whose facilities were engineered to accomodate black and white signal origination.

Also instrumental in the early development of color TV penetration was the fact that the first six years following the product's introduction were punctuated by three years of general economic recession--one year of moderate recession and two years of more severe general economic conditions. Sales of consumer durables are generally sensitive to general economic conditions; and, sales of consumer electronics appear to be particularly sensitive.

TABLE 3
Color Receiver Sales
(000,000 units)

Year	Sales	Cumulative Sales
1953	0	0
1958	.1	.2
1963	.8	1.8
1968	5.0	10.8
1973	10.0	60.4
1978	10.7	103.2
1983	14.0	163.0
1984	17.2	180.0
1985	16.9	197.0
1986	19.0	216.1

Source: 1987 Electronic Market Data Book, EIA Marketing Services Department.

For these and other reasons, sales of color TV sets languished until the fourth quarter of 1961, a year after the close of the 1959 recession, and did not really "take off" until 1962. Thus, it took about 8 years for sales of color receivers to reach the 1% household penetration threshold. Summary data are included in Table 3.

Videocassette Recorders VCRs were first introduced in this country in 1975. Roughly half of US homes now have a VCR, a fact which testifies to the very rapid US household adoption of this technology and product line. Well over 80% of the installed VCR base has apparently been manufactured in the past five years. Consumer uncertainty about the relative values of VHS and Beta formats dampened early sales as did a brief and mild recession beginning in mid-1978. For many years cassettes were not readily available in all locales and, where they were available, the selections were neither diverse nor expansive.

The best estimate available suggests that about 4.5 million units were imported between 1975 and 1982. Most of these remained in dealer inventories or elsewhere in the distribution pipeline. Accounting for these differences between imports and consumer sales, it appears that 1% household penetration was probably reached sometime during 1981 or 1982--some 6 or 7 years after VCRs were first introduced. (See Table 4.)

TABLE 4
Videocassette Recorder Factory Sales
(000 units, $000,000 value)

Year	Units	Value
1976	30	-
1977	250	$ 180
1978	415	325
1979	488	388
1980	802	620
1981	1,471	1,126
1982	2,020	1,303
1983	4,127	2,162
1984	7,881	3,585
1985	11,786	4,738
1986	13,533	5,257

Source: 1987 Electronic Market Data Book, EIA Marketing Services Department

Television Receive-Only Earth Stations Penetration of TVROs has been fairly erratic since their introduction into the marketplace. Uncertainty as to the lawfulness of taking pay television signals off the air and the future availability of unscrambled signals undoubtedly discouraged many potential buyers. The decision of major satellite program distributors to scramble their signals and the inaccessability of decoders in some areas may have dampened the growth of TVROs.

It is difficult to date the introduction of TVROs for consumer use. Receive only earth stations were in commercial use long before higher powered, and otherwise more advanced, satellites permitted design and use of smaller, lower priced versions suitable for household entertainment purposes.

Although the Niemann-Marcus Christmas catalog touted a very expensive model in 1977 or 1978, only a handful of TVROs were installed before 1980. By 1981 there were between 5,000 and 20,000 installations, many of which were at commercial establishments--hotels, motels, neighborhood bars and the like. It appears that about 1 million units were sold to US dealers during 1981 and 1982. Many, of course, remained in dealer inventories. Thus, the limited information available suggests that 1% household penetration may have been reached in 1986 or 1987, some six or seven years after the "introduction" of TVROs into the consumer market.

In one very important respect, however, the "years to 1% household penetration" measure substantially underestimates the diffusion rate among "eligible" households. Because of space and zoning limitations in urban and suburban locations, the effective market for TVROs has been predominantly in rural areas. If the market were redefined to reflect those realities, the first stage would be a couple of years shorter and the current penetration would be several points higher. The weight of these observations is not, however, sufficient to alter the ATV product scenarios developed below.

Projection Television Receivers Large screen projection color televisions have been available in the US for about a decade. To date, however, total sales to US dealers have been somewhere between 1.5 and 2 million units. A large but unknown percentage of these have been purchased for use in commercial establishments rather than in households. Taking that into account and assuming a 3 to 1 inventory to sales ratio indicates that the 1% penetration rate has not yet been reached. At current rates of sales growth, the 1% threshold probably will not be reached for another three or four years. This implies that it may take this product line twelve to fourteen years to reach the threshold.

Home Computers These were first available in 1975, when about 500 were sold. Sales reached 100,000 units in 1978. The proliferation of videogames and other hobbyist oriented software began to lift personal computer sales dramatically. Prices declined and the range of product available increased to broaden consumer choice. Recent sales history is summarized in Table 5. By 1982, sales to US dealers were in the neighborhood of 2 million units. It appears that the first stage of the product cycle for home computers was completed in the 1981-1982 time frame, or about six to seven years after the product line was first introduced into the marketplace.

TABLE 5
Home Computer Factory Sales
(000,000 units, $000,000 value)

Year	Units	Value
1982	2.0	1,300
1983	4.8	1,950
1984	5.1	2,250
1985	4.1	2,050
1986	3.8	2,890

Source: 1987 Electronic Market Data Book: EIA Marketing Services Department

Audio Stereo Component Systems It is difficult to track the development of these systems, because they are not in fact a single product line. Components include receivers, tuners, amplifiers, speakers, turntables, headsets and a variety of accessories. There is no requirement that the components be combined by all users in the same way or purchased together as a single unit. Indeed, those features give users great flexibility and appear to be one of the strongest attractions of component systems. Systems can be individually tailored and upgraded, or otherwise enhanced, on a piecemeal basis as new components become available in the market and/or household budgets permit.

System components were individually available on a limited basis to aficionados in the fifties and somewhat more widely during the sixties. But, component sales barely dented the commanding market position of combination units until the mid-eighties. Throughout the seventies, it appears that combination systems outsold component systems on the order of 10 to 1. The real impetus to sales of component systems came with the availability of inexpensive audio tape equipment, which provided both a substitute for and a complement to the traditional combination "player" component--the turntable.

On the basis of limited and somewhat ambiguous data, our best guess is that the 1% penetration threshold was reached sometime around 1976--about two decades after component systems first became available to US consumers. (See Table 6)

TABLE 6
Audio Component System Factory Sales
(000 units, $000,000 value)

Year	Units	Value
Pre '76	900	-
1976	245	-
1977	300	-
1978	414	-
1979	394	-
1980	178	80
1981	200	89
1982	319	144
1983	403	178
1984	1,540	729
1985	2,335	1,046
1986	2,158	1,050

Source: 1987 Electronic Market Data Book: EIA Marketing Services Department

Summary Table 7 brings together the early sales history of our set of six consumer electronic products by presenting estimates of how long it took each product line to reach the 1% household penetration threshold. Projection television and audio component systems stand apart from the cluster embracing the other product lines. A variety of reasons can be advanced for the relatively poor market performance of projection TVs. They are bulky and require large viewing areas for maximum visual performance. They are also still rather "pricey" a decade after their introduction, although models embodying different technologies are beginning to address both of those problems. The history of audio component systems sales also falls well outside the norm for the sample. Since we are not sure what is actually being measured by the data, there does not appear to be sufficient reason to assign much weight to this product history.

What is more striking than the exceptional cases of projection TV audio component systems is the tight cluster of initial market development times for the other four product lines. These early diffusion rates are remarkably similar and tentatively suggest a consistent pattern of consumer response to new, home entertainment related electronic devices.

TABLE 7
Years to Achieve 1% U.S. Household Penetration for Selected Consumer Electronic Products

Product	Time Interval (years)
Color TV Receivers	8
Videocassette Recorders	7-8
TV Receive Only Antennas	6-7
Home Computers	6-7
Projection TV Receivers	12-14
Audio Component Systems	20

D. STAGE II--GROWTH AND IMITATION

In this section we will explore further the historical growth path of selected consumer electronics products. The eligible set of products has diminished, however, due to the fact that two of the selected product lines are quite immature. As indicated above, sales of TVROs and projection television receivers are still fairly modest and clearly have not broken out of the first stage of diffusion. Their immaturity is only partially attributable to their relative youth. The fact is, owing to several forces operating in those markets, they may never take off.

For present purposes, the key question is whether ATV products will mimic the more or less tepid market performance of TVROs and projection TV, or emulate more nearly the growth experience of the more successful lines. Put differently, are the factors accounting for the growth patterns of TVROs and projection TVs likely to hinder the growth of ATV products as well?

The residential TVRO market has been predominantly driven by demand for television signals in areas not served by cable television. The decision of program distributors to scramble those signals reduced the value of the earth station to all users and, for those with adequate reception of terrestrial signals, scrambling did not leave much residual value for an earth station. Until decoders are made more readily available at modest expense, the market may well continue to languish with additional sales limited mainly to households without access to cable or strong terrestrial signals; or to those with a very strong preference for specialized program signals, religious broadcasts for example. Continuing reductions in average "dish" prices will, however, stimulate residential installations.

In the context of the potential demand for ATV products, the TVRO experience sends out a clear signal for caution. Growth will be quite dependent on the availability, quality, and diversity of compatible programming. Improved visual images are important, but consumers apparently may not support the expense of ATV products on that basis alone, particularly if they are restricted in their program choices.

The implications of the projection TV market for ATV products are rather more opaque. While there are now three different techologies available, the popularity of rear projection models points to the simple "bulk" of combination units as a barrier to wider consumer acceptance. Related, of course, is the fact that the distance required between the viewer and the screen to minimize annoying visual distortions is larger than the available viewing areas in most US homes.

Finally, the sluggish national economy in 1982 significantly dampened sales in both 1982 and 1983, thereby suppressing the growth of the installed base and the opportunity for potential buyers to observe a receiver outside of dealer showrooms. This opportunity has been important in the diffusion patterns of other consumer durables, since it is a valuable source of consumer information about new products, and because it feeds the incentive of more conservative buyers to emulate pioneers.

Whatever the reasons for the failure of these two product lines to take off, the other four have grown quite remarkably since reaching the 1% threshold of household penetration.

Color Television Receivers After the 7-8 year introductory period, consumer purchases escalated rapidly and, in the first five years thereafter, sales doubled every fifteen months.

The growth of color TV sales has been remarkably steady over the product's life. The general growth path has been interrupted only by periodic economic recession. In 1986 US consumers spent more than eight billion dollars on color receivers alone. Over the 30 odd years since color television was first introduced, US consumers have purchased almost 220 million sets. Roughly 100 million of these have been sold in the last five years, clearly indicating that the market has not come close to saturation, despite the fact that about 92% of US homes now contain at least one color set.

Between 1962, when 1% household penetration was first reached, and the latest year for which data are available, units sold grew at a compound annual rate (CAGR) of over sixteen percent--from about 400,000 units to well over 19 million units in 1986.

Sixteen percent CAGR over a twenty-five period is remarkable by almost any standard but, taken by itself, that growth rate does not adequately describe the historic path of color TV sales. The twenty-five year average growth rate is distorted by a purely statistical phenomenon which is endemic to most growth rate calculations. As mentioned above, a given absolute gain in sales will look relatively larger in the early years of a product's life than later. Thus, a fuller picture of color TV growth can be described by examining growth over different intervals of the product's history.

TABLE 8
Color TV Sales Growth Rates for
Selected Intervals
(nearest %)

	Actual CAGR	Smoothed CAGR
Eight Year Intervals		
1962-1970	37	40
1970-1978	9	7
1978-1986	5	8
Five Year Intervals		
1962-1967	65	65
1967-1972	10	10
1972-1977	10	10
1977-1982	5	7
1982-Present	11	9

Note: Since 1970 and 1982 were recession years in which sales declined, the data were smoothed by use of a simple average of the values for years before and after the years of decline.

The size of the time segment chosen is arbitrary. Two years are not very interesting and fifteen masks a lot of interesting variation. Table 8 shows growth for two intermediate intervals--five year and eight year time segments after 1962, the 1% threshold date. These numbers give more definition to the color TV growth path. Two rates for each interval are included in the table--one is the actual rate and the other, in parentheses, is calculated after the data were "smoothed" to take out the distorting effects of the 1970 and 1982 recessions, each of which fell on one of the interval endpoints.

We believe the most useful information, for present purposes, is reflected by the data grouped in five year intervals after adjusting for the 1982 recession. Both the five and eight year groupings show dramatic growth following 1% penetration, followed by solid but slower growth in subsequent time periods. Both breakdowns show growth surging in the mid-eighties when the general model of product diffusion creates the expectation that growth would continue, diminish, flatten or become negative.

Several sources for the unexpected strength of this market have been advanced. The average service life of a color set has been estimated to be on the order of seven years. This means that the replacement market alone will be about 15% of the installed base each year. Estimates of the installed base vary, but the most commonly cited figures center around 125 million units. Thus, replacement of aging units will support sales of around 19 million units this year. And, since the installed base has been growing, replacements alone will fuel sales growth for the next few years. Of course replacement can be deferred, but that rate depends on several factors, including maintainence and repair costs, but more important determinants relate to product prices, qualities and the level of household income. (The ability of consumers to defer replacement of aging NTSC sets may provide a source of liquidity for sales of ATV products.)

There is little doubt that the major source of strong color receiver sales in the mid-eighties has been attributable to the strong impetus to consumer spending generated by general macroeconomic conditions in the past five years. Growing real income, relatively stable prices, declining costs for consumer credit, high employment rates, and very importantly, the strength of the dollar in world currency markets have all contributed to generally strong US markets for consumer durables.

The strength of the dollar has probably been the single most important factor underlying the surge of color receiver sales in the past five years. The increased value of the dollar has been largely responsible for the fact that the television receiver (all types including black and white) component of the consumer price index declined by over twenty-three percent from 1981 to 1986, while the consumer price index as a whole was increasing by over 18%. Thus, receivers were not only getting cheaper relative to other goods and services, their prices actually declined by almost a quarter over the five year period.

It is also signficant, we believe, that some of the solid state components of receivers have become less expensive in all currencies; and, that new manufacturing "process" technologies using workers from previously underutilized offshore labor pools have contributed to the more efficient and less costly production of all consumer electronics products, including color television receivers.

Lest we stray too far from the main focus of this paper, we should emphasize that these sources for recent growth in the sales of color receivers are not guaranteed to recur in ways that will assure a similar impact on ATV products. Although history does sometimes repeat itself, it can be argued that the confluence of forces described above is very unlikely to recur during the life cycle of ATV products. Thus, the growth path of ATV products may well be less steep in the out years than our experience with color TVs might indicate.

Videocassette Recorders Earlier analysis indicated that VCRs reached the 1% penetration threshold in 1981 or 1982. In either event the time interval since is quite narrow, thereby making pretty lean the data for characterizing the post-threshol growth path.

By 1986 factory sales to US dealers had reached more than 13 million units, valued at over $5 billion. Not all of these sales to dealers have reached US households. The best available estimate has it that about half of US households now contain a VCR. Thus, in about thirteen years, VCR sales have gone from zero to 50% household penetration. Over the four year interval 1982 to-1986, VCR unit sales grew almost sevenfold, or at a CAGR of better than 60%, thereby describing an "early take-off" growth path remarkably similar to that of color televison receivers.

Caution is warranted, however, before inferring that ATV products will enjoy similar success in the domestic marketplace. The quite favorable confluence of macroeconomic forces described above in the context of the market for color TVs have come to bear with equal force in the domestic market for VCRs. Although an equally congenial economic environment may well materialize during the late nineties when ATV products are expected to be at a similar stage in the market development cycle, it is just as conceivable, and likely, that economic forces in the aggregate will be somewhat less hospitable to growth in consumer electronics products.

Our purpose here is not to make a macroeconomic forecast for the nineties, but only to emphasize that general economic conditions have been, and will be, quite instrumental in the market performance of these product lines.

Home Computers It may be argued that home computers are evolving into a class of products quite dissimilar to ATV products and, for that reason, their respective market growth paths may be subject to entirely different market forces. Although home computers were in the beginning used in large measure for home entertainment purposes, recent developments suggest that other nonentertainment uses are coming to be more important. The hint for this development is found in software sales. Whereas game oriented software initially provided the bulk of software sales, in recent years utility programs for personal financial planning, tax preparation, word processing, a variety of educational tutorials, and programs designed for assorted specialized nonentertainment oriented purposes are among the most rapidly growing.

Sales of home computers have grown substantially but erratically in the past five years. Volume measured in the number of units sold peaked in 1984, but the value of dollar sales has continued to grow even though prices for "commodity" products have declined. Newer, more versatile and powerful models have been introduced. The average value of a sale has increased in the past five years, indicating that the composition of sales is shifting toward more technically robust and expensive units.

This development confirms the suspicion expressed earlier that the primary use of home computers is shifting, since utility programs frequently require more sophisticated hardware than many of the game programs used for home entertainment. In short, the growth path of home computers may be tracing two different product lines--the rise and flattening of video game machines and the birth/infancy of a market for more sophisticated applications.

Notwithstanding these bases for cautiously applying the home computer market experience to ATV products, the data, we believe, still have some relevance. First, the data show the willingness and ability of households to make fairly large expenditures on new consumer electronics products--even in a more or less volatile market being churned by price changes, new product introductions and uncertain product quality--in the context of a fairly immature set of supporting industries.

Despite all of this, there are now computers in about one in five US homes some twelve years after their introduction. Annual sales have more than doubled since the 1% threshold was reached, which implies a CAGR in the neighborhood of 20%.

Audio Component Systems We have indicated that data tracking the early development of sales in this product line were difficult to interpret. Data describing sales behavior over the last decade are even less clear-cut. The 1978 sales peak of about 400,000 units was apparently not surpassed until 1984 when sales roughly quadrupled over the preceding year. This was a rather stagnant market until three years ago. After the great leap forward in 1984, sales grew a little over 50% in 1985, only to fall off again in 1986. It could very well be that the gains over the past three years are ephemeral, if the surge in sales represents the product of a temporary combination of very favorable macroeconomic forces, described earlier, rather than the beginning of a secular trend which is sustainable over a longer period of time.

Given the uncertainty suggested by the market history of audio component systems and the ambiguity involved in clearly defining the product for sales measurement purposes, we cannot comfortably infer from it much of value to our efforts to construct a plausible scenario for the development of ATV products.

Summary and Synthesis Taken together, the growth histories of these six selected consumer electronic product lines paint a somewhat dappled picture of possible growth paths for ATV products. Summary data are compiled in Table 9.

Optimists can find comfort in color TV receiver and VCR markets. Pessimists can find striking counterpoints in market histories of projection TVs and audio component systems. Those with a penchant for the middle road can find a fairly good candidate in the development of the home computer market. While we had no good reason to expect otherwise, there are some clear differences in the patterns emerging from the growth histories of these six product lines.

Despite the ambiguities and contradictions in the product histories, a couple of fairly consistent patterns are evident.

Four of the product lines--color TVs, VCRs, TVROs and home computers--share a strikingly common early product history, with each taking 6-8 years after introduction to achieve 1% US household penetration. We believe the product histories of audio component systems and projection TVs can each be written off as more or less *sui generis*. That is not to say, however, that we cannot easily conceive a set of economic, regulatory and political events which would result in a decade or more of sluggish ATV consumer product sales which more or less track the experience of less successful consumer electronic product lines. But, more on that below.

TABLE 9
Diffusion Patterns: Household
Penetration by Selected
Consumer Electronics Products

	Audio Systems	Color TV	VCRs	TVROs	Home Comptr.	Projection TV
Years to 1% HH. Penetration	20	7	7-8	6-7	6-7	12-14
CAGR-Five Year Intervals						
0-5	flat	65%	60%	-	20%	-
5-10	30-40	10	-	-	-	-
10-15	-	10	-	-	-	-
15-20	-	7	-	-	-	-
20-25	-	9	-	-	-	-

Source: Base data from Electronic Market Data Book for selected years, EIA Marketing Services Department. Calculations and estimates by Author.

A second unlikely coincidence directly relevant to the future of ATV products is the near identity of the early growth patterns of color TV receivers and VCRs. This is an important consistency since these are the two consumer product lines most likely to be introduced in versions which embody ATV technologies. Each attained substantial household pentration in the decade following its introduction; and each grew at rates which resulted in tenfold increases in sales during the first five years after "take off".

IV. ATV PRODUCT GROWTH SCENARIOS

The task in this section is to interpret the growth histories reviewed previously in the specific context of potential markets for ATV products.

Although ATV products are at various stages of development and under the sponsorship of several different organizations, only one company, NHK, has announced a firm production schedule. Indeed, only the NHK systems have been field tested under actual broadcast conditions. We are not able at this time to offer more than conjecture about the possible production schedules of the other contenders. Our impression is that the principals themselves are by no means firm in their expectations. For purposes of constructing the ATV consumer product market scenarios, we will assume that only NHK patent licensees will offer product at retail to US consumers within the next five years.

NHK has announced plans to have available for worldwide distribution, under the terms of licensing agreements with eleven Japanese manufacturing firms, 100K MUSE receiver units in 1990; 500K units in 1991; and, to be able to satisfy retailer demand during 1992. Production is expected to reach 1.5 million units in 1992. According to NHK representatives, players of videocassettes and discs will also be available during that time frame. The expected quantity and timing of shipment of these products to dealers are, however, less clearly expressed by NHK.[10]

The availability of cassette and/or disc players is critical since, initially at least, there will very likely be little, if any, programming available from other distribution media--cable, satellite and over-the-air broadcasting. Supposing even that additional spectrum necessary to distribute MUSE and other ATV signals is made available by the FCC in Docket 87-268, there will be a substantial lag before an appreciable amount of programming will be available in ATV formats to US households. Although some compatible programming is available, in particular, feature films shot in 35mm formats, production of current programs will require substantial station investment in new studio equipment.

The upshot of all of this is that there are significant barriers to widespread and immediate acceptance and purchase of ATV products upon their being made available. Nevertheless, the barriers are not in essential respects qualitatively different from those confronted initially by color television receivers and VCRs. Yet, both product lines fairly quickly overcame both compatibility and program/signal scarcity much like those being considered here in the context of ATV products.

A. SCENARIO 1--SLUGGISH DIFFUSION

Earlier sections of this report cite a variety of technical, regulatory and market barriers to quick and widespread diffusion of ATV products. There is no good basis for supposing that the full, potentially adverse effects of these barriers will in fact be realized. Similarly, there is insufficient reason for discounting completely such an outcome.

The fact is that a combination of regulatory delay and uncertainty, a sour economy, and a shift in consumer saving and buying patterns, for example, could seriously constrain market penetration rates. And, since there has been, to our knowledge, virtually no meaningful market research on consumer acceptance of these products in this country, it may be that consumer preferences for improved television images--though quite positive--are simply not strong enough to support the rather healthy household budget commitment required to obtain these products.

There are several ways to characterize a sluggish penetration scenario. Product introduction may be delayed, as in the case of AM stereo; the product may require several years to achieve the 1% market penetration threshold, as in the case of projection TV; the market may subsequently manifest slow growth like audio component systems, or erratic growth like home computers.

Even more pessimistically, the market may simply may not materialize, as was the case with picturephone, videotext, and a host of other failed consumer products. The high current visibility of ATV products could, in short, turn out to be much ado about very little.

Recognizing that several sluggish scenarios can be developed, the one characterized here is consistent with the following general conditions:

-Continuing uncertainty about spectrum constraints and receiver standards;

-Delay in R&D programs directed to competing technologies, systems and products;

-Periodic or prolonged domestic macroeconomic conditions involving some combination of slow growth, substantial government deficit reduction programs, flattening or declining real consumer spending and unfavorable employment conditions;

-High and rigid ATV product prices; and,

-Weak revealed household preferences for ATV products.

Should these illustrative conditions materialize, wholly or in part, it is quite conceivable that the one percent threshold would not be realized until well after the year 2000, and that subsequent growth would also be dampened. For example, 1% household penetration by the year 2003, fifteen years hence, would generate sales of slightly over one million units each of advanced VCRs and ATV receivers, thereby replicating the historic growth of projection TV sets.

Depending on the pattern of product prices over that period, the cumulative value of sales could be in the $3 to $5 billion range, as defined by hypothetical average product prices of $1500 for advanced VCRs and $2500 for ATV receivers.

Should ATV product sales languish in this fashion, there is little basis, a priori, for expecting any particular growth rate for subsequent periods. However, in keeping with the generally pessimistic outlook of this scenario, consider that 10% CAGR over the subsequent five year period would generate sales of 600,000 to 700,000 units of each product in the 2003-2008 time frame. Using the same set of hypothetical prices, this translates into an additional one to one-and-a-half billion dollars in revenue.

To summarize our "gloomy" scenario, a combination of adverse economic developments could severely repress household penetration of these technologies and result in tepid sales performance over the next 20 years. Under the very general conditions posited here, sales would be negligible over the next decade. Total sales in the $4 to $6.5 billion range might materialize, but the bulk of those would not be realized until after the turn of the century. These sales volumes are by no means trivial but, viewed in the context of 1986 sales of NTSC color receivers of over $6 billion, neither are they impressive.

B. SCENARIO 2--RAPID PRODUCT DIFFUSION

This scenario is more optimistic. It is consistent with more favorable economic conditions than those supporting Scenario 1. For ATV products to enjoy rapid diffusion among US households, both the economic and regulatory environments must be congenial. As indicated earlier, during the eighties US retailers have enjoyed unprecedented growth in sales of consumer electronic products.

In the past five years, sales of consumer electronics products have grown at a compound annual rate of nearly 20%. About 40% of those sales were accounted for by NTSC color receivers, a very mature product line, and conventional VCRs, which represent a very young product line. More importantly, perhaps, is the fact that these are the product lines that the new technologies and systems seek to replace.

Whether or not performance of the domestic and world economies will support continuation of secular consumer spending patterns on electronics products is outside the scope of the study. If it does, even approximately, the growth paths of NTSC color TV receivers and VCRs may be replicated by kindred products embodying ATV technologies. That eventuality summarizes, in a nutshell, the conditions underlying this scenario.

More specifically, this scenario also requires:

-Timely and decisive regulatory action respecting receiver standards and spectrum limitations;

-Accelerated R&D programs leading to product diversity and active price competition;

-Sufficient sales in the first ten years to avail producers the opportunity to exploit scale and learning economies; and,

-Rapid development of high quality, moderately priced, compatible program supply sources.

Should these conditions materialize, the historic path of their NTSC predecessors may well provide a reasonable template for the future growth of similar ATV products. Scenario 2 is based on the following assumptions: one per cent household penetration 7-8 years after introduction, 60% CAGR for the five years following, and steady, if unspectactular, growth thereafter of 10% per year, driven by product replacements, production cost and price reductions and significant, but unspecified, product improvements.

ATV Receiver Growth Scenario Table 10 incorporates these conditions and summarizes the results for color TV receivers. Beginning in 1987 with 1 million units sold and growing them at 60% for each of the next five years yields sales of about 10.5 million units by 2002. Simultaneously growing current households at 1.5% per year and then taking the ratio with the illustrative installed base suggests nearly 25% household penetration in 2002, some twelve years after the introduction of ATV compatible receivers. If sales were to grow subsequently at an average rate of 10% for each of the next five years, the household penetration would exceed 90% some two decades after introduction and the installed base would accumulate to over 100 million units, even after allowing for replacement of aging units.

TABLE 10
Product Development Scenario:
ATV Compatible Receivers
(000,000 units)

Year	Annual Sales (units)	Cumulative Sales (units)	Household Penetration (%)
1997	1.0	1.0	1.0
1998	1.6	2.6	1.5
1999	2.6	5.2	4.8
2000	4.1	9.3	8.5
2001	6.6	15.9	14.4
2002	10.5	26.4	23.5
2003	11.5	37.9	33.2
2004	12.7	50.6	43.7
2005	14.0	64.6	54.9
2006	15.4	80.0	67.0
2007	16.9	96.9	80.0
2008	18.6	115.9	93.9

VCR Growth Scenario The growth path of VCRs using ATV technologies is subject to uncertainties even beyond those permeating the color TV scenario sketched out above. During the early years of ATV product availability, it appears that VCRs will most likely be an indispensable complement to TV receivers, without which the receiver will have little value. The bulk of the early programming will come from existing libraries or 35mm film which will be processed electronically to make it compatible with the ATV format.

The VCR will very likely be the first medium available for distributing ATV programming and, for a while, it may well be the only one of any consequence for most US households. The cable, terrestrial broadcast, and satellite industries will have an incentive to reconfigure their respective distribution systems only when there appears to be sufficient household demand to warrant undertaking the necessary investments. However, significant community demand for cable or out of the air programming should materialize when the installed ATV compatible base of TV receivers reaches some substantial level of household penetration. And, whatever that level of penetration might be, it can only be supported by high levels of early VCR sales as necessary adjuncts to receivers.

Thus, for the first few years, VCR sales and sales of a new generation of ATV cassettes should track very closely the installation of receivers. For how long this will persist is an open question which will be resolved only by the rate at which the other distribution media adjust their systems to the ATV distribution format.

Early availability of compatible programming over other media will sever the one to one nexus between receivers and VCRs by increasing the value of stand-alone receivers and reducing the scarcity value of VCRs as a distribution medium. The future potential interplay of these industries and the strategic options of the players are fascinating but beyond our limits to explore here.

TABLE 11
Product Development Scenario:
Videocassette Recorders
(000,000 units)

Year	Annual Sales (units)	Cumulative Sales (units)	HH Penetration (%)
1997	1.0	1.0	1.0
1998	1.6	2.6	2.4
1999	2.6	5.2	4.8
2000	4.1	9.3	8.5
2001	6.6	15.9	14.4
2002	10.5	26.4	23.5
2003	9.2	35.6	31.2
2004	10.2	45.8	39.5
2005	11.2	57.0	48.5
2006	9.2	66.2	55.4
2007	10.1	76.3	63.0
2008	11.2	87.5	71.1

For purposes of this scenario, we will characterize VCRs and receivers as necessary complements, or technologically "tied" products, for the first five years after introduction with equal unit sales in each year. After 2002 when about a quarter of US households may, according to this scenario, own an ATV compatible receiver, there may be sufficient programming available from other media to begin to break the VCR/receiver bond. Thereafter, the scenario characterizes VCR unit sales each year falling to 80% of receiver unit sales for three years, then to 60% for the final three years of the scenario.

The sales and household penetration implications of these characterizations are presented in Table 11. VCR sales track receiver sales until 2002, achieve nearly 25% household penetration, then begin a new, basically flat, growth period which boosts penetration to about 70% (compared to 94% for receivers) in twenty years after take off.

Combined Market Value of Product Scenarios Table 12 combines the results of the two product line scenarios and values unit sales by applying a range of hypothetical product prices.

TABLE 12
Market Value of Scenario Growth Paths
(000,000 units, $000,000,000)

[illegible] inflation
1998$

Year	Cumulative Sales Receivers			Cumulative Sales VCRs			Total Value of Sales	
	Units	Value		Units	Value		Value	
		High	Low		High	Low	High	Low
1997	1.0	$.8	$.4	1.0	$.6	$.3	$1.4	$.
1998	2.6	2.0	1.0	2.6	1.5	.75	3.5	1.
1999	5.2	4.2	2.1	5.2	3.1	1.5	7.3	3.
2000	9.3	7.4	3.7	9.3	5.6	2.8	13.0	6.
2001	15.9	12.7	6.4	15.9	9.5	4.8	22.2	11.1
2002	26.4	21.0	[illegible]1.5	26.4	15.8	7.9	36.8	19.4
2003	37.9	30.3	1[illegible].6	3[illegible].6	21.4	10.7	51.7	25.3
2004	50.6	40.5	20.2	[illegible]5.8	27.4	13.7	67.9	33.9
2005	64.6	51.6	25.8	[illegible]7.0	34.2	17.1	85.8	42.9
2006	80.0	64.0	32.0	6[illegible].2	39.7	19.8	103.7	51.8
2007	96.9	77.5	38.7	76.3	45.8	22.9	123.3	6[illegible].6
2008	115.5	92.4	46.2	87.5	52.5	26.2	144.9	72.

The relationship between product prices and the rate of household penetration is one of mutual interaction. Cause and effect goes in both directions. Recalling our earlier discussion of demand, production costs and pricing policies, it is clear that prices must come down substantially if the sales volumes and penetration rates depicted here are to be realized. The market scenarios give up any claim to realization without substantial decline in the $3,000 introductory prices expected for each product.

Trends in both component technologies and production technologies support expectations that prices will decline precipitously over time. Further, the technological and economic histories of microelectronics based industries give every reason to expect that VCR and receiver functions, along with others perhaps, will be merged into a single piece of equipment priced below the total of the stand-alone prices. One can easily imagine numerous other developments which will have a bearing on product specifications, costs, quality and price--all of which will shape the willingness of households to replace NTSC equipment.

The long and short of it is that specifying prices for these products a decade from now is pretty much guesswork. For purposes of illustration Table 12 is calculated for a "high" value and a "low" value. Receiver sales are valued on average at $800 and $400 per unit and VCR sales at $600 and $300. All dollars are current. These average values are well below the introductory prices now being quoted. Introductory prices must come down for the scenario penetration rates to be attained.

The dollar values contained in Table 12 clearly reflect the fact that unit sales were developed without regard to product price, a practice which is clearly inconsistent with expected and historic consumer behavior. Specifically, the scenario suggests that unit sales will be the same in each time period under both the high and low price assumptions. There is no reason to believe that product demand will exhibit that kind of price inelasticity. Thus, the range in total market valuations based on the high and low set of product prices is overstated by a factor which varies with product price elasticities, since unit sales would surely be higher (lower) when prices are lower (higher). Adjusting quantities for the different assumed price levels would change the "naive" sales figures in Table 12 which simply ignore the unknown price elasticity effects.

It is important to be as clear as possible about this assumed set of prices as they affect the market valuation of sales. We are aware of market valuation estimates that assume product prices in the neighborhood of $1500 for an ATV receiver. The penetration rates derived in this scenario are very likely unattainable if product prices substantially lower than that are not achieved.

Moreover, since the demand for these products is likely to be price "elastic" (in a technical economic sense), lower prices imply higher total sales revenue, since a relatively small percentage reduction in price will, given the definition of "elasticity", stimulate a greater percentage increase in the number of units sold. Thus, the boost in revenue from greater volume should exceed the negative revenue impact of lower prices so that, on balance, the net effect of a price reduction is to increase the value of sales.

Is this scenario realistic? It is not if one is looking for point estimates of market sales data for these products in the future. It also goes without saying that the further into the future we look, the less confidence we can have that underlying forces have been either captured or accurately represented in their potential impact.

This scenario is as realistic as the key assumptions which underlie it. We believe that those assumptions are not unreasonable; nevertheless, it is useful to review them in a summary fashion. Proceeding from the more general to the more specific, they include:

-Healthy world and domestic economies;

-High levels of consumer spending on electronics products;

-Favorable product development and pricing trends;

-Timely and decisive resolution of critical receiver standards and spectrum questions;

-Vigorous competition among several product sources and technological systems;

-Reasonable replication of market histories of other US consumer electronic product lines--particularly VCRs and color TV receivers; and,

-Widespread availability of compatible ATV software.

Realization of these necessary conditions would permit ATV compatible receivers and VCRs to reach $3-4B in sales within a decade and to top $50B within the next fifteen years, if the "high" value totals in Table 12 for the years 1998 and 2003 accurately embody the forces which will drive this market.

Of course, the interested and arithmetically inclined reader can easily create other quite reasonable scenarios by simply changing the assumptions and working out the results. Two key assumptions are that it will take seven years to reach 1% household penetration and that the market will grow at 60% CAGR for the first five years thereafter. These standards were met by both color TV receivers and VCRs in the marketplace, but they are indeed ambitious. They can be achieved in ATV product markets in the future only if the necessary conditions spelled out above generally prevail.

C. COMMERCIAL/INDUSTRIAL AND GOVERNMENT APPLICATIONS

The market for ATV products will be driven by entertainment applications of the technology in the home, as indeed are current R&D programs and production plans. Even modest penetration of 90M US households will generate sales well beyond the levels likely to be attained by sales to government, commercial and industrial users. The reason is the magnitude of the US consumer sector, its buying power and its appetite for entertainment related electronic products. Thus, the sheer size of the U.S. consumer market dwarfs any other subset in the market classification developed above and may, in fact, compare not unfavorably with all of the others taken together.

To illustrate, the revenues generated if 7% of U.S. households spent $1,500 each on ATV products would amount to about $9 billion.

Total Defense Department procurement by 1990 is expected to be on the order of $80 billion.[11] Defense is the principal potential government user of ATV products, yet it is difficult to imagine a scenario in which as much as one or two percent of the Department's total procurement would be allocated to expenditures on these ATV products. Even those levels would generate relatively small revenues compared to the hypothetical household spending of $9 billion posited above. Thus, DOD would have to spend over one percent of each year's procurement budget on ATV related products over the next decade to approximate the level of economic activity associated with seven percent of US households spending $1,500 each.

Looking at spending by DOD from a different angle, the Defense Department is currently spending about $6 billion annually on research, development, testing, and evaluation in all categories of electronics and communications.

The potential for industrial and commercial uses also pales in comparison to potential household demand. In 1986 the total value of all shipments of graphics displays, special purpose graphics terminals and computer monitors (CRTs) was a little over $2 billion. CAT scanner sales were about a half billion dollars. While total spending on all types of electromedical equipment exceeded $5 billion, over 95% of those expenditures can be eliminated as completely insulated from the availability of new ATV products.

This is not to say that government and commercial uses of ATV products will be inconsequential. Rather, we expect that entertainment oriented uses of such products will simply overwhelm commercial applications in the foreseeable future.

Some commercial applications are specifically entertainment oriented. These types of products will promote and be promoted by the development of consumer products oriented applications. Studio production equipment, large segments of broadcast transmission equipment, electronic equipment in cable distribution systems and a variety of other NTSC compatible gear will have to be replaced if and when those standards are changed.

Recent testimony before the House Subcommittee on Telecommunications and Finance of the Committee on Energy and Commerce is helpful in estimating the potential value of this market segment. The principals of the New York Institute of Technology estimated the cost to a broadcast station owner of converting to a standard other than NTSC. They placed the cost at $4.5 million per station, or about $6 billion if all current stations were to convert.[12] This is by no means a negligible market, but it assumes less importance when placed in some additional perspective.

First, station owners are not going to convert until household penetration of equipment is substantial, or until the growth path of home entertainment devices is unmistakably clear. Secondly, the smaller the station the greater the burden of the additional investment and the lower the expected return from converting. The economics of small market broadcasting may not support these levels of investment. Finally, the estimated cost per station to convert to a new ATV standard does not reflect the potential for significant production economies if huge demand were to materialize in a relatively short period of time.

Our search for applications of ATV technologies outside of the entertainment field turned up several pockets of interest and potential demand for specialized commercial applications. These include:

-Medical diagnostic applications;

-Retail telemerchandising applications;

-Teleconferencing applications;

-Industrial quality control;

-Various training and simulation devices; and

-Various CAD/CAM applications.

We are unable to estimate the total potential value of markets for these applications without substantial further analysis. It is quite possible, though, that the dominant industrial uses of the technology will be in entirely new applications which have yet to be identified. It is humbling in this context to recall that an early forecast of total US computer sales proclaimed total potential demand to be "no more than a dozen".[13]

To summarize, commercial and governmental applications, though by no means inconsequential, are not, on the surface at least, sufficiently robust to qualify as much more than a marginal adjunct to the consumer market. The most likely prospect is that there will be numerous special applications of the technology customized for particular nonentertainment uses. This is not to imply that these markets should or will be ignored. For purposes of this analysis, however, our summary review of non-household applications suggests that the market for ATV products will be dominated by the rate of product adoption by households.

D. OTHER ECONOMIC EFFECTS OF ATV DIFFUSION

The discussion thus far has been directed toward establishing the market value potential for the sale of ATV products to households, commercial/industrial concerns and government. Whatever those sales might amount to in time, they do not exhaust or fully characterize the economic activity likely to be induced by the introduction of ATV products in either the short or the long run. The purpose of this section is to elaborate on the direct impact of ATV product sales and to explore a range of indirect effects of ATV market development.

The scenario results were expressed in terms of potential dollar sales of ATV products under different economic conditions. These final sales reflect the summation of incremental market values added by agents at various stages in the upstream production chain. The value of assorted materials, components, capital, labor and managerial resources "used up" in prior production processes are reflected, albeit anonymously, in the final sales price. At each intermediate stage of production required by the demand for final ATV products jobs are created, taxable income created, profits earned and wealth accumulated.

It requires immense effort to identify and quantify the various strands in this web of economic activity. Fortunately, some work has already been done which begins to unravel some of the key relationships.

Employment Effects ATV sales will create jobs both here and abroad. The split will be determined by the ability of US producers to compete successfully. The best analysis available for understanding the domestic employment implications is contained in a study performed for the Consumer Electronics Group of the Electronics Industries Association by Arthur D. Little, Inc.[14] Based on extensive research, personal interviews and the use of a Department of Commerce "input-output" model of the economy, the study was able to identify and quantify a variety of economic impacts originating with domestic production of consumer electronics products.

The study reports 1983 US employment and domestic value added (net of imported goods) by category of consumer electronics products. Taking the ratio of these study estimates yields a crude estimate of the average relationship between the value of domestic content and employment. Column 1 in Table 13 displays the results of this reorganization of the A. D. Little data for selected product categories.

TABLE 13

Employment and Multiplier Effects of
ATV Product Sales Growth

Product Line	Value Added per Worker	Value Added Multiplier	Employment Multiplier
Color TV Receivers	$28,000	2.8	2.8
Videocassette Recorders	27,000	2.0	2.0
Video Tape	28,000	3.4	3.2
Other Video Products	27,000	2.4	2.4
All Consumer Electronics	27,000	2.7	2.7

Source: Arthur D. Little, Inc.

The interpretation of the numbers is straightforward. On average in 1983, sales of consumer electronics products valued by end users at $27-28,000 required the creation of one job. Alternatively, this implies that every $1B worth of value added created by US consumer electronics suppliers is associated with about 35,000 US jobs. These jobs are scattered throughout the economy--manufacturing, service, utilities, trade and transportation, for example. They represent the _direct_ employment created in the electronic products production chain.

Multiplier Effects The income and employment impacts of the activity are not exhausted by direct sales and direct employment. Workers employed in electronics and supporting industries, investors there, and others deriving income in those sectors will use the proceeds to buy other goods. Suppliers of those goods will hire other workers, buy other goods, and so on. There is, then, a secondary "multiplier" effect which will magnify the domestic income and employment impact of increased production of ATV products. This multiplier will generate a substantial stream of indirect or secondary income and employment effects.

Multipliers derived from the Arthur D. Little, Inc. study are also displayed in Table 13. The value-added and employment multipliers were each about 2.8 in 1983 according to that study. This means that for each job or dollar of income generated directly by domestic production of consumer electronics and complementary goods/services, an additional 1.8 jobs or dollars will be generated indirectly. A. D. Little estimates that the total of direct and indirect activity will be 2.8 times the amount generated in the first instance.

It may be helpful to put these effects in the context of the scenario for ATV consumer product sales developed above. We will use the years 1998 and 2003, ten and fifteen years hence, to illustrate. From Table 10 we read ATV compatible receiver (unit) sales in those years as 1.6 million and 11.5 million units, respectively. Assuming each unit sells for $600, direct value added is $960 million in 1998 and $6.9 billion in 2003. The Arthur D. Little "value added to jobs ratio" described above ($1 billion value added means 35,000 jobs) implies that this level of ATV receiver sales would would be associated with over 240,000 jobs in 2003 and 35,000 jobs in 1998. Similar calculations using data on VCR sales from Table 11 are possible, as are calculations for other years.

These income and employment impacts assume that the entire value added in the production of these products is the result of economic activity in the US, i.e., there are no imported components or materials and no offshore fabrication, for example. It further assumes that production processes will not become less labor intensive between now and then. Although neither of these assumptions is likely to be realized, the exercise still graphically illustrates the powerful direct employment impact this technology could have on the domestic economy.

Taking into account the induced income and employment effect of these sales requires, according to A. D. Little estimates, increasing the direct income and employment effects by a factor of 2.8. Continuing with the VCR example and performing the arithmetic yields $2.7 billion in (direct plus indirect) sales and almost 100,000 jobs by 1998. Bear in mind that total employment in 1986 for all US consumer electronic industries was about 63,000.

Again, we want to emphasize that we are not forecasting these levels of income and employment impacts. They rest on a series of assumptions and calculations which, for a variety of reasons, may ultimately prove to be in error. Nevertheless, the arithmetic is very instructive, for it demonstrates the economic forces which may be mobilized, or lost, as a result of the development of ATV systems and products.

Fiscal and Trade Impacts The income and employment effects of the level of ATV related economic activity suggested in the foregoing scenarios would create substantial pressures on the current balances in both the US trade and fiscal accounts. Full exploration of the effects of those pressures is beyond the purposes of this study, but even a superficial analysis indicates the enormous potential leverage of ATV market development on the twin deficits.

In 1986 the US posted a trade deficit of almost $17 billion in the electronic products account, of which $14.5 billion (85%) originated in consumer electronics products alone. Factory sales of TV receivers and VCRs to dealers in the US were roughly $12 billion, the overwhelming bulk of which were imported. Total US exports of consumer electronics products in 1986 were about $1.2 billion, while exports of electronic parts were in the neighborhood of $2.7 billion.[15]

These data confirm that home video products are a major source of the deficit and, consequently, a line of business where some potentially remedial steps might generate substantial payoffs. That is the good news. The bad news is that the trade account could be dramatically worsened if US households do not have a domestic option for ATV products and instead satisfy their entire demand for these products from sources abroad.

To get a rough idea of the relative importance of the potential market for ATV products in the context of the current trade balance, refer back to Table 12. The mid-point of the range of cumulative value-added between 1997 and 2003 is $38 billion, which is about $6 billion a year on average. That is roughly half of the the 1986 deficit in the trade accounts generated by imported NTSC receivers and VCRs. We hasten to caution that these calculations are based on a long list of assumptions, not all of which have not been explicitly stated or justified in this report. The calculations are intended, nevertheless, to illustrate a general conclusion which is all but unassailable, namely, that the market potential for ATV products in this country implies dramatic potential effects on the balance of trade.

The levels of economic activity associated with potential domestic value-added in the production of ATV products will generate taxable national income earned by both corporations and households. Further, by increasing domestic employment, domestic production of these products will tend to dampen employment sensitive federal, state and local government expenditures. A full analysis is beyond the scope of this report. However, a crude indication of the relative impact of ATV related value-added is suggested by the fact that federal tax receipts are running at a rate of about a quarter of national income. While we are not able to quantify reliably the potential fiscal effects of the ATV penetration scenario, they are clearly both positive and too large to ignore.

E. THE MARKET OUTSIDE THE US

Western Europe The potential European market for ATV products has such substantial economic appeal and offers so much political and cultural opportunity that industry and governments have joined in a concerted effort to stake out an early claim by agreeing on common European ATV equipment and transmission standards. The EUREKA project, by any standard measure, has been very successful. The European Economic Community has adopted the MAC standard for direct broadcast satellite transmission while maintaining compatibility with existing receivers and protecting, at least in the short term, the value of investment in equipment engineered to PAL or SECAM standards. The MAC systems being installed in Europe today can easily accomodate migration to HDTV and the plans are to do so beginning in 1992.

The European MAC system will offer at the margin substantially greater value-added to European consumers. The system is engineered to provide a data channel; to provide the opportunity for viewers to choose whatever language they desire for commentary or sound "dubbing" of films; and to provide several stereo audio signals. The system will also be compatible with existing cable television distribution systems.

Given the close economic linkages across the North Atlantic, European and US consumers will be subject to many of the same economic forces described earlier in the development of the US household scenarios. Thus, the rate at which the European market develops is also quite dependent on general economic conditions over the next decade and beyond.

Our approach to describing the European ATV market potential is to compare current European patterns of spending on electronic products to US spending and to use those relations as the basis for making inferences about possible market development rates in Europe.

Table 14 permits comparison of spending on selected electronic products categories in the US and in Western Europe. Roughly 75% of European sales are generated in West Germany, the

U.K., France and Italy. The data indicate that the European market has recently been about half the US market in major categories of spending on electronic products.

TABLE 14
Comparative Spending on Selected
Electronics Products (1986):
US and Western Europe

Product Class	Europe	US
Total Electronics Sales ($B)	97	198
Consumer Electronics Sales ($B)	15	29
Video Equipment Sales ($B)	8.6	17.7
Television Receivers (000,000 units)	16.0	22.0
Videocassette Recorders (000,000 units)	7.8	13.5

Source: 1987 Electronic Market Data Book: EIA Marketing Services Department for US data; and, Yearbook of World Electronics Data--1988--Western Europe, Volume 1, BENN Electronics

The exception to that pattern is spending on TV receivers. The relative strength of European receiver sales may reflect in part the fact that TV sets are less ubiquitous in Europe (around 35% population penetration) than in the US (50% population penetration). Thus, more European sales are probably to households without a TV than is the case in the US where about 98% of all households have at least one set. Secondly, we expect that the strength of VCR sales may lift the demand for receivers in Western Europe to a much greater extent than in the US, due to differences in the availability of alternative distribution media and programming.

The foregoing suggests that ATV products may well achieve faster diffusion and higher growth in Western Europe than in the US. For present purposes we will assume that the sales over time in Europe will at least match the US growth rate, but on a base that is only one-half as large. Using that rule of thumb and applying it to the optimistic US scenario developed above, the resulting European scenario suggests a market for ATV receivers and VCRs in the neighborhood of $25 billion by the year 2003. That is about three times the amount spent on video equipment in Western Europe in 1986 and implies that such spending will grow at about eight percent a year, a rate which is by no means unreasonable in view of the substantial value added for consumers by the MAC technology.

Japan There are about 31 million television sets registered in Japan according to recent estimates. Since registration requires payment of a receiver tax, there may be more actually in use. Sales in the past three years alone sum to about 15 million units. Penetration of TV receivers in Japan is significantly less (254 sets per 1,000 population) than in the US or Western Europe. Almost 17 million VCRs have been sold to Japanese consumers in the past three years. Sales for the next three years have been projected to be closer to 18 million.[16]

In view of the progress made in Japan in virtually every aspect which is required to hasten the introduction and growth of ATV products, there is every reason to expect that product diffusion and market development there will exceed the rates suggested above for the US and, probably, Western Europe. Government and broad segments of the Japanese electronics industries are united in their efforts to meet a commonly accepted schedule for making compatible product and program distribution media available. This reflects a strong, clear and unified national commitment to promote the technology within both domestic markets and abroad. And, of course, NHK has a demonstrated technology and a well-defined production schedule. These conditions contrast sharply with the technological, regulatory, political and economic uncertainties cited above as characterizing the US environment.

Under any conceivable timetable for resolving the uncertainties in the US and making available US produced ATV products, NHK and their manufacturing licensees will have an enormous headstart in the Japanese market. Moreover, this experience will very likely be leveraged to great advantage in other world markets and in the US in particular.

V. IMPLICATIONS FOR THE MICROELECTRONICS INDUSTRY

The electronics industries make up a vast complex with numerous and frequently subtle linkages among their parts. Observers have likened the structure of these industries to an integrated fabric, a food chain, a seamless web or a pyramid with semiconductor materials and manufacturing equipment/processes at the apex, which is the residence of the technological wherewithal for providing a broad range of commercial and consumer product applications.

The decline of US leadership in this important sector is amply documented. Several large scale research efforts and numerous technical papers have addressed and attempted to isolate its causes and consequences.[17] Our purpose here is decidedly more modest and the discussion will focus on the general nature of the linkages between the consumer electronics sector and the broader set of electronics industries, particularly the semiconductor industry.

The consensus view is disturbing. Loss of leadership in semiconductor production will breed dependency and lack of competitiveness in a broad array of downstream information industry product lines. Integrated circuitry has become as ubiquitous as energy as a necessary input into industrial and commercial processes. Indeed, it is almost impossible to find a line of commerce that does not rely in important respects on products and services embodying microelectronics technology. Factory automation, instrumentation, military hardware and systems, retailing, banking, as well as a great variety of consumer goods are increasingly driven by the information processing and storage capabilities of semiconductor technology.

The Office of Technology Assessment concluded a massive study of US competitiveness in electronics with the observation that, "[I]f there is any single industry whose technological progress and competitiveness are critical to the economic growth and national security of the United States, it is electronics."[18]

A similar view was expressed in a study originally prepared for the Joint Economic Committee of the US Congress: "For the foreseeable future, the relative economic strength of all advanced industrial economies will rest in part on their capacity to develop and apply semiconductor technology to product design and production processes."[19]

Nor is this view limited to US experts. The President of a major Italian electronics firm observed in 1986 that, "[A]s soon as the leading role of an enterprise in the development of semiconductors is lost, it becomes dependent upon the supplier of base technology and is degraded to being a dealer in electronic systems produced by others; and, when it no longer has command over semiconductor technology, it loses control over its own industrial fate."[20]

There is little dispute about the key role to be played by this technology in the development of national economies. The question of greatest interest here, however, centers on the potential contribution of large scale participation in the manufacture of ATV products to the development of the domestic semiconductor industry. To put it differently, it is clear that semiconductors will be important to ATV product development, but how important will the production of ATV products be to the future development of the semiconductor industry? In what follows we will attempt to sketch the broad outlines of an answer.

One of the more striking historical changes in the semiconductor market is the transformation of its major user base. The semiconductor market in this country initially was driven almost exclusively by government demand for defense and space applications. Growth in commercial and industrial uses quickly outstripped government demand in the sixties and early seventies, so that by 1978 government purchases accounted for only about one-tenth of total sales of semiconductors in the US. The truly high growth sector in the past decade has been neither government nor the commercial sector, even though together they continue to command a high percentage of semiconductor output.

Consumer electronics applications, which were negligible in 1970, accounted for over 30% of total world consumption of integrated circuits by 1984. Much of the early demand was for use in watches, calculators, handheld games, and assorted toys. More recently, however, some of the more advanced product lines, including VCRs and limited intelligence TV receivers, have accounted for a growing share of total integrated circuit use.

Notwithstanding these worldwide trends, the share of the output of the US semiconductor industry destined for consumer electronics products has declined significantly during the past five years. Our best estimate, based on discussions with several industry experts, is that about 5-6% of US semiconductor output was incorporated into consumer products in 1986. In sharp contrast, almost one-third of Japanese semiconductors were shipped to, and used by, the consumer electronics sector in that year.

The ATV systems and products now under development will very likely lead to quantum increases in the demand for signal processing and storage capability, which in turn will require incorporation of several fairly sophisticated chips. Different system designs will have different requirements and both spectrum availability and receiver design standards will influence the amount of intelligence required in these consumer products. But, almost any conceivable outcome will boost demand for integrated circuitry substantially. For example, to convert a MUSE signal to make it compatible with NTSC receivers requires a converter consisting of four circuit boards, which will in the future be composed of five VLSI chips.

If the recent past is prologue, firms which capture substantial shares of the US consumer electronics market will tend to manufacture those products using components which they, or their close affiliates, manufacture. Put differently, it is doubtful that US imports of ATV products will include much in the way of US value-added components, including semiconductors. A recent estimate indicates that Japan accounts for about 40% of world consumption of semiconductors, much of which is incorporated into consumer electronics products, while less than 10% of Japanese consumption of semiconductors is of US origin.

A chain of reasoning which clearly demonstrates some of the more important linkages under consideration here appears in the Report of the Defense Science Board Task Force on Defense Semiconductor Dependency.[21] This Report, which provided much of the impetus for the SEMATECH consortium, concluded:

-US military forces depend heavily on technological superiority to win;

-Electronics is the technology that can be leveraged most highly;

-Semiconductors are the key to leadership in electronics;

-Competitive, high-volume production is the key to leadership in semiconductors;

-High-volume production is supported by the commercial market;

-Leadership in commercial volume production is being lost by the US semiconductor industry;

-Semiconductor technology leadership, which in this field is closely coupled to manufacturing leadership, will soon reside abroad;

-US Defense will soon depend on foreign sources for state-of-the-art technology in semiconductors. The Task Force views this as an unacceptable situation.[22]

There are other important synergies between semiconductor materials and manufacturing processes, the level of semiconductor sales, and downstream activities like manufacture of ATV products. The following are suggestive of some of these relationships and spillovers:

- Scale economies in semiconductor production are more readily attainable in the presence of high volume demand from the consumer electronics sector;
- To the extent that common production processes are used, the cost of semiconductors for other uses will be lower as a result of the high volume demand from the consumer products sector;
- The cost of R&D for a wide range of applications can be amortized across the consumer electronics driven base;
- The fairly stable demand for consumer electronics products can provide insulation from the more volatile demand for semiconductors from other sectors;
- There appear to be both economies of vertical integration and economies of scope;
- Vertically integrated firms can use revenues from the consumer products and semiconductor lines to contribute to development of new processes and new products both upstream and downstream;
- High volume production of semiconductors gives rise to "learning" economies which increase the proportion of circuits that function, thereby driving down the average cost and price of salable output;

These relationships indicate the nature of some of the linkages that exist in the network of information markets and industries. The point here is not to detail those relationships, but to establish that the development of a US market for ATV products will have important collateral effects spread throughout the electronics and information industries complex.

VI. CONCLUSION

The potential wealth that may be generated in world markets for ATV products over the next twenty years is astounding. Whether and to what extent that potential will be realized in ways consistent with US interests is an open question.

The details of the scenarios do not really matter. Under a broad range of alternative assumptions, the scenarios imply that future development of this technology may offer both enormous opportunity and significant risk to US interests. This conclusion holds even if the technology develops only at a fraction of the pace and replicates only partially the success of its consumer electronics predecessors.

The scenarios also make clear that our technological and economic futures cannot be separated from each other or insulated from the consequences of US government policies and implementation.

What various agencies of the US government do, or do not do, will have an immense effect on the distribution of world technological, economic and political power created by this family of technologies during the next twenty years and beyond.

These results do not, standing alone, imply that the government should or should not take any particular steps in the processes now under way to develop this family of technologies.

However, viewed in the broader context of challenges to US technological leadership in microelectronics and electronics products more generally, the potential magnitude of the stakes involved in the consumer electronics sector testifies to the importance of a careful review of federal policies, programs, and regulations which influence the incentives of potential US participants.

NOTES

1. For a good summary see Federal Communications Commission, *Notice of Inquiry in the Matter of Advanced Television Systems and Their Impact on the Existing Broadcast Service*, MM Docket No. 87-268; Released: August 20, 1987. Also, Comments of William F. Schreiber, *Document 1: Analysis and Recommendations*, Response to the Notice of Inquiry in MM Docket No. 87-268.

2. For an excellent summary review of the technical and qualitative parameters of the various systems, see Schreiber, *Document 1*, pp. 3-10.

3. *Comments of NHK--The Japan Broadcasting Corporation*, MM Docket 87-268, p. 10.

4. *Notice of Inquiry in the Matter of Advanced Television Systems and Their Impact on the Existing Broadcast Service*, MM Docket No. 87-268; Released: August 20, 1987.

5. Michael E. Porter, *Competitive Strategy: Techniques for Analyzing Industries and Competitors* (New York: Macmillan Publishing Co., 1980), ch. 10.

6. Estimates provided by the National Telecommunications and Information Administration.

7. For an extensive discussion of the process of "diffusion" see, Everett M. Rogers, *Diffusion of Innovations* (New York: Macmillan Publishing Co., 1983).

8. There are now approximately 90 million US households with growth expected at about 1.5% per year. The 1% household penetration volumes are based on this growth path.

9. This history is extensively developed in Hugh M. Beville, Jr., "The Product Life Cycle Theory Applied to Color Television" (MBA diss., New York University, 1966). See also, James E. Millstein, "Decline in an Expanding Industry: Japanese Competition in Color Television," in *American Industry in International Competition: Government Policies and Corporate Strategies*, eds. John Zysman and Laura Tyson (Ithaca: Cornell University Press, 1983), 106-141.

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10. *NHK COMMENTS*, p.10.

11. Data in this section were taken, unless otherwise noted, from various tables in *1987 Electronic Market Data Book*, EIA Marketing Services Department (Washington, DC: Electronic Industries Associations: 1987).

12. Karen G. Glenn and William E. Glenn, "Testimony of the New York Institute of Technology," October 8, 1987, before the House Subcommittee on Telecomunications and Finance of the Committee on Energy and Commerce, pp. 12-13.

13. James Martin, Future Developments in Telecommunications, 2nd ed. (Edgewood Cliffs: Prentice-Hall Inc., 1977), p.11.

14. Arthur D. Little, Consumer Electronics: A $40-Billion American Industry (Washington, D.C., Electronics Industries Association/Consumer Electronics Group, April 1985).

15. 1987 Electronic Market Data Book.

16. MacIntosh Yearbook of World Electronics Data-1988-Japan, vol. II, (BENN Electronics).

17. Thomas R. Howell, William A. Noellert, Janet H. MacLaughlin, and Alan Wm. Wolff, The Microelectronics Race--The Impact of Government Policy on International Competition, (Boulder and London: Westview Press, 1988); Michael Borrus, James E. Millstein, and John Zysman, "Trade and Development in the Semiconductor Industry: Japanese Challenge and American Response," in American Industry in International Competition: Government Policies and Corporate Strategies, eds. John Zysman and Laura Tyson (Ithaca: Cornell University Press, 1983), 142-248. Michael Borrus, Laura D'Andrea Tyson, and John Zysman, "Creating Advantage: How Government Policies Shape Trade in the Semiconductor Industry," in Strategic Trade Policy and the New International Economics, ed. Paul R. Krugman (Cambridge: The MIT Press, 1987), 91-114.

18. International Competitiveness in Electronics (Washington, D.C.: U.S. Congress, Office of Technology Assessment, OTA-ISC-200, November 1983), 463.

19. "Trade and Development in the Semiconductor Industry", 143.

20. Quoted in The Microelectronics Race, 7.

21. Office of the Undersecretary of Defense for Acquisition, Report of Defense Science Board Task Force on Defense Semiconductor Dependency (February 1987) (Washington, D.C., DTIC File Copy, AD-A178 284), 1-2.

22. Ibid.

UNITED STATES DEPARTMENT OF COMMERCE
The Assistant Secretary for Communications
and Information
Washington, D.C. 20230

December 24, 1987

Mr. Alex Felker
Chief
Mass Media Bureau
Federal Communications Commission
1919 M Street, N.W.
Washington, D.C. 20554

Dear Lex,

High Definition Television

It is my pleasure to be serving with you on the FCC Advisory Committee on Advanced Television Systems. Chairman Patrick has initiated a process which I hope will end with a U.S. strategy on the future of advanced television in this country. I applaud him for this initiative.

Some months ago, the National Telecommunications and Information Administration held a conference on advanced television. We did so for several reasons. We wanted to get senior leadership more involved with this public policy issue. We wanted to seek advice on developing an advanced television policy for this Administration. And, as a part of the Department of Commerce, we wanted to begin an assessment of the economic implications of technological advancements in high resolution technology in a number of markets, including consumer electronics.

We were most appreciative that you participated in our conference. We, therefore, want to share with you some of the views that are, in part, an outgrowth of the conference.

We believe a primary goal of any initiative should be to make HDTV feasible for terrestrial broadcasting. We have come to this view, not because we favor broadcasting over other video distribution systems, but because unlike such other systems (e.g. Cable and VCR), terrestrial broadcasting is uniquely constrained by government regulations from readily adopting this new technology. The FCC's existing spectrum allocation scheme for television and related technical standards raise issues which must be accommodated if HDTV technology is to be adapted to the broadcast medium and government action will be required. VCR manufacturers and cable companies are not so constrained and can, through wire-lines which they control, reconfigure their spectrum at will. Terrestrial broadcasting is not so fortunate.

Additionally, while important, our concern is not limited to broadcasting being at a unique, government-driven disadvantage in responding to the HDTV opportunity. We also feel that the federally fostered local television system will be needlessly jeopardized if steps toward making HDTV feasible for terrestrial broadcasting are not taken. The video market is most competitive when, as is the case today, state-of-the-art technology is used by all media. It is not easy to maintain competition in the marketplace, however, if there are marked technical quality differences among competitors. If terrestrial broadcasting cannot accommodate the new technology, it almost certainly risks being left behind by competing video delivery systems able to provide high definition service. We believe that local television, with its strong traditional commitment to local news and other service, should not be put at risk of a prolonged decline, much in the way that the AM radio was allowed to decline vis-a-vis higher quality FM service.

In our view, the FCC's Advanced Television study should result in the commencement of a rule making proceeding, which would declare as its intention, the establishment of an HDTV broadcast transmission standard by a specific date. We have suggested 1991 as an appropriate target. At least four important benefits should flow from the selection of a single HDTV broadcast transmission standard. First, given the substantial progress that has already been made toward creating an HDTV system suitable for terrestrial broadcasting, three years afford sufficient time for further innovation. Second, by announcing a target date, the Commission will serve notice on firms engaged in development of HDTV that our terrestrial broadcast media will deliver HDTV, and will deliver it in about the same timeframe as other media. Third, consumers will be given the same sort of assurance that terrestrial broadcasting will be part of the HDTV future. Fourth, terrestrial broadcast television will be given an opportunity to maintain its place as a competitive, state-of-the-art video technology.

We recognize that any Commission standard setting proceeding will involve balancing a number of variables. First, the HDTV broadcast transmission standard must be as spectrum efficient as possible. While we have an open mind on the use of additional bandwidth, a 6 megahertz solution in accord with existing allocations, would clearly be more easily implemented. Additionally, we think it is important that any HDTV system adopted as a transmission standard generate a signal compatible with existing NTSC sets, such that viewers will be able to receive virtually the same quality of service on existing sets. There will also necessarily be signal quality trade offs between proposed competing HDTV transmission systems. Any final terrestrial broadcast standard for HDTV will have to be evaluated in the light of these factors and achieve the proper balance.

It is also important to understand that by this proposal, we do not mean that the FCC should establish an HDTV transmission standard for any other video distribution systems, or that the Commission should involve itself with standard setting for TV sets or other receiver hardware. We believe an HDTV broadcast transmission standard is the key and set manufacturers can be expected to design sets capable of decoding the broadcast transmission standard ultimately agreed upon.

Our concern is that this process begin; that the Commission announce its determination to set a standard by 1991. Such an announced intention would provide increased certainty and a very real target on which HDTV transmission system designers can fix their sites. Again, this would be a standard for HDTV broadcast transmission only, not more.

Should you be interested, a fuller development of these thoughts is set forth in our comments filed with the FCC in the Advance Television proceeding. I very much look forward to working with you as we seek to meet what I believe is the greatest challenge facing television for the remainder of this century.

Sincerely,

Alfred C. Sikes

cc: Dennis Patrick
Richard E. Wiley, Esq.

The Brookings Institution

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Foreign Policy Studies Program

August 24, 1989

Senator John Glenn
Chairman
Committee on Governmental Affairs
United States Senate
340 Dirksen Senate Office Building
Washington, D.C. 20510

Dear Senator Glenn:

At the invitation of Mr. Harry Broadman, of your committee, I would like to submit the following statement for consideration by the committee. I believe you will find it relevant to your inquiries into the conflicting assessments of the potential economic impact of HDTV.

I thank you for the opportunity to present my views to your committee.

Sincerely,

Kenneth S. Fl

Dr. Kenneth Flamm
Senior Fellow

Enclosure

HDTV and DRAMs: A Critical Assessment

Kenneth Flamm[1]

In hearings held by the Senate Commerce, Science, and Transportation Committee in May of 1989, it became clear that for at least several key supporters of a Federal initiative in High Definition Television (HDTV)[2], the primary objective would be to help the U.S. semiconductor industry, upstream. These producers would presumably find it easier to sell their chips in large volume to an American-controlled HDTV industry than to a foreign-based producer.

The logic runs something like this. The market for HDTV receivers and recorders is going to be a potentially huge source of demand for semiconductors. Selling into that market is essential if a semiconductor producer is to be competitive on manufacturing cost, because of economies of scale and scope, as well as the honing of basic manufacturing process skills in the fabrication of high volume chips. American chip producers will be able to enter this vast new market easily only if American HDTV producers are active. Therefore, an HDTV program's top priority is to "grow" a large consumer electronics sector to which a revitalized American semiconductor industry can then deliver its product.

This semiconductor "trickle down" case for HDTV rests on a number of implicit assumptions. It is assumed that "American" production of HDTV is a market opportunity that will be exploited by American chip makers. That is, selling HDTV chips will be a profitable market, and U.S. chip makers will invest in leading edge technology in this area. While this assumption is not one I wish to debate, it is a very important one. While it may be argued that such an "American" market is necessary to give American chip producers a chance to sell[3], such a domestic market is at best a necessary but not sufficient condition: witness the fact that we now have "American" firms designing over half of the world's shipments of computers, yet purchasing 80 to 90 percent of the memory chips going into those machines from foreign vendors. This would suggest that creating a vast American HDTV chip market only makes sense if seen as part of a broader program which makes it highly certain that American chip companies have the product and technology to sell into that market. And if that is the case, shouldn't the American chip industry-- the object of all this commotion-- be brought up front and center for scrutiny when policy is designed?

Another point I will not belabor is how large the HDTV business will eventually grow by the middle of the next century. Such crystal-ball gazing is irrelevant to some suggested big-ticket policies being put forward at the moment, which focus on relatively short-term objectives. A billion dollar investment in HDTV production facilities might be obsolete in ten years, and some credible voices argue that entirely different technologies, designed to serve a digital, fiber optic communications networks, will be the economic choice as we build a national information infrastructure, a backbone for our emerging high-tech economy, over the coming decades. If that is to be the case, it might make more sense to leapfrog the obsolescing analog HDTV transmission technologies of today, and reach for the digital, fiber optic network of tomorrow. A crash program to get product out the door within the next few years only makes sense-- as a policy to aid the U.S. semiconductor industry-- if the HDTV semiconductor market mushrooms sooner rather than later.

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[1] Dr. Flamm is a Senior Fellow at the Brookings Institution, 1775 Massachusetts Ave., N.W., Washington, D.C. 20036. This document reflects only his personal opinions and should not be construed as reflecting the opinions of other staff members, officers, or Trustees of the Brookings Institution.

[2] The Defense Advanced Research Projects Agency (DARPA) is to date notable as the only government organization to back up enthusiastic verbal appreciations of the technology with cash ($30 million). This may seem like a very modest sum. But it is about half again as much as DARPA is spending annually on high temperature superconductivity.

[3] Without getting into the complex merits of this point, some argue that foreign markets are closed and therefore inaccessible to American producers, or that close technical collaboration with the R&D laboratories where these products are designed is essential to timely product development, or that standards-setting procedures favor national firms.

The crucial foundation to all talk of HDTV as a "driver" for the semiconductor industry is the assertion that it will soon be sufficiently large as to constitute a significant chunk of semiconductor demand. But it is clear over the medium term (that is, by the first decade of the next century) that under even a rather optimistic scenario for HDTV, coupled with a pessimistic view of the growth of world semiconductor sales, HDTV would at most account for only a small percentage share of aggregate semiconductor consumption in the United States or the world.[4]

Some respond by asserting that these calculations overlook a significant fact, that HDTV's share of the market will be much greater for certain high volume, mass-produced products-- notably dynamic random access memory chips (DRAMs)-- which today probably account for over one fifth of open market integrated circuit sales revenues, and play a disproportionately important role in the development of leading edge semiconductor manufacturing technology. The principle analytic support for these contentions about the specific role that HDTV will play in DRAM consumption has been recent Congressional testimony by Dr. Craig Fields, of the Defense Advanced Research Projects Agency. Dr. Fields has supplied a set of graphs to Congress (see figures 1 and 2) which seem to show that within a decade, by 1999, DRAM consumption in HDTV will surpass such consumption in what is now the primary application, in computers.

Unfortunately, the DARPA graphs which seem to establish this surprising proposition are based on questionable assumptions. By changing just two parameters-- the amount of memory configured in a computer, and the growth of memory per computer over time-- to more realistic values, the entire analysis is turned on its ear. Even when very conservative values-- selected to understate DRAM usage in computers-- that more closely approximate the historical record are used, the remainder of the DARPA assumptions suggest that an HDTV initiative is unlikely to create anything more than a marginal increment to the DRAM market over the next several decades.

Figure 4 shows what happens to DRAM usage in computers when memory usage per computer is assumed to grow at a conservative but constant 20 percent annual rate. The actual growth rate over four to seven year periods has been in the 25 to 40 percent range, historically, going back to the mid-1960s, and shows no signs of falling toward zero, as DARPA has projected.[5] Memory usage per computer in 1987 has also been adjusted toward a historically more accurate figure. DARPA's original estimates for projected unit computer shipments have been retained.

DARPA's HDTV shipment forecasts are also on the highly optimistic side. Figure 3 compares the DARPA forecast of unit HDTV sales with the American Electronic Association's forecast of worldwide sales of HDTV receivers and VCRs. In 1999, when HDTV is projected to roll past computers, the DARPA series on HDTV sales is an entire order of magnitude (power of 10) greater than the AEA estimates! Figure 4 also shows DRAM usage in HDTV when DARPA's methodology is applied to the AEA projections of HDTV sales. Again, the original DARPA thesis is reversed. Other evidence, discussed in the appendix, also suggests that the DARPA estimates fall well short of actual DRAM consumption in computers as you read this, in 1989, before the future has even begun.

Betting that DRAM consumption in HDTV will exceed that in computers any time in the foreseeable future does not appear to be a very attractive wager. Consider figure 5, which portrays

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[4] See my remarks and those of Senator Gore at the May 16 hearing; also Congressional Budget Office, "The Scope of the High-Definition Television Market and Its Implications for Competitiveness," (July 1989), pp. 20-23.

[5] See the appendix.

MOS memory
[redacted] consumption by major use in Japan, in 1988. Even in Japan, the dominant power in the consumer electronics world, computers and office automation accounted for almost 80 percent of memory chip consumption.[6] Video cassette recorders and color TV together accounted for less than six percent of consumption.

The purpose of this exercise is not to argue that support for research in high resolution imaging, or displays, or data transmission, is an inappropriate expenditure of government resources. Indeed, I believe that the historical record shows quite convincingly that information technologies have been very worthwhile research investments in the past for our Nation.

But good policy is built in a framework based on fact and analysis. There may be a good case for a crash program to chunk out HDTV receivers in 1995 lurking in the woods, somewhere. But basing policy on the premise that HDTV will revitalize U.S. DRAM production would seem to be a waste of precious time, and scarce resources, as far as the competitive problems of the American semiconductor industry are concerned.

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[6] MOS memory includes not just DRAMs, but also static random access memory, erasable programmable memory, programmable read-only memory, and read-only-memory. DRAMs probably account for about 60 percent of sales in this category.

Appendix

The DARPA Graphs

The graphs introduced by Dr. Fields show actual and projected shipment of HDTV receivers and computers, worldwide, and DRAM consumption associated with these shipments. They are reproduced as figures 1 and 2 of this document.

To understand what these figures imply, it is useful to conceptualize the demand for DRAMs in an economically meaningful way. Historical data can then be used to come up with reasonable ranges for parameters determining the growth of DRAM consumption.

DRAMs are an input used in the production of a capital good, so it is helpful to write the "derived demand" for DRAMS in, say, computers, as

(1) $D_t = d_t \ C_t$

where D_t is ***total*** *demand for DRAMs in year t, d_t is DRAMS used* ***per computer****, and C_t is total computers sold. We would normally expect d_t to increase as memory prices drop, as would C_t, since falling memory prices induce a similar decline in computer price. C also depends on the overall pace of economic growth, and its stimulating effects on business investment in computers. If we assume that both memory prices and economic expansion continue near recent historical rates, it may be reasonable to suppose that d_t and C_t will also continue to increase at rates in line with recent historical experience.*

Expression (1) can be rewritten as

(2) $D_t = d_0 \ (1+g)^t \ C_0 \ (1+h)^t$

with subscript 0 denoting base levels in some starting year, and g and h annual growth rates for DRAMs per computers, and computers shipped, respectively, from year 0 to year t.

Underlying the DARPA graphs, then, are assumptions about the base consumption of DRAMs, growth rates for DRAMs consumed per unit shipped, and growth rates of units shipped, for both computers and HDTV. The key parameters implicit in the DARPA graphs are summarized in Table 1. (Note that the unit in which "number" of DRAMs is measured appears to be 1 megabit chip equivalents.[7])

Table 1
DARPA Assumptions

	Computers	*HDTV*	*Computers*	*HDTV*
	Million Units Sold (C_0)		*Megabits DRAM per Unit (d_0)*	
1987	*17.5*	*0*	*0*	*32*
1992	*30*	*2.5*	*8.3*	*32*

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[7] This is confirmed by noting that units of HDTV shipped, multiplied by 32 megabits, yields the DARPA estimate of DRAM consumption in HDTV.

Table 1 (cont.)
Compound Annual Growth Rates (%)

	Computers	*HDTV*	*Computers*	*HDTV*
	Million Units Sold (h)		*Megabits DRAM per Unit (g)*	
1987-92	*11*	*n/a*	*n/a*	*0*
1992-97	*10*	*57*	*22*	*0*
1997-02	*10*	*31*	*7*	*0*
2002-07	*10*	*12*	*2*	*0*

The DARPA analysis starts with an assumption of 0 DRAMs consumed in computers and HDTV in 1987. This is a significant error. Calculations based on estimates from Dataquest, a marketing research company, suggest that DRAM consumption in computers shipped to the U.S., Western Europe, and Japan alone exceeded 121 million units in 1987.[8]

Data from Integrated Circuit Engineering, another market research firm, suggest that 156 million megabits of memory sold in the open market were consumed by computer and office automation equipment producers worldwide in 1987. That number probably rose to 280 million megabits in 1988.[9]

From 1992 to 2007, unit shipments of computers worldwide grow at a roughly constant 10 percent per year in DARPA's forecast. This is not grossly unreasonable, but is probably on the low side. Statistics from the Computer and Business Equipment Manufacturers Association show U.S. unit consumption of computers (micros, minis, and mainframes) growing at about 16 percent per year over the relatively slow growth period of 1984-87, and forecasts a 14.5 percent annual growth rate over 1988 to 1998. In high-growth periods, these annual growth rates have typically been 40 to 60 percent.[10]

HDTV receivers, by way of contrast, are projected to grow at 57 percent per year from 1992 to 1997, and 31 percent from 1997 to 2002. These projections are at the very high end of the very diverse projections available on HDTV growth, and in 1999 are about a full order of magnitude (i.e., a power of 10) greater than projections developed by the American Electronics Association. This is illustrated in figure 4, which compares DARPA's extremely optimistic HDTV forecast with the (merely) optimistic

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[8] This estimate is derived as follows: Dataquest estimates of the **value** of 1987 DRAM sales to data processing equipment producers in the U.S., Western Europe, and Japan were divided by a Dataquest estimate of average cost per bit of memory in 1987. A remarkably similar figure is produced by multiplying a conservative estimate of average bits of memory per computer, based on Dataquest data for 1987, by DARPA's estimate of worldwide shipments of computers for that same year.

[9] This calculation takes 68 percent (ICE's estimate of the share of U.S. DRAM sales absorbed by computers and office automation in 1987) of ICE's 1987 and 1988 estimates of the total number of bits of DRAM memory sold in the open market. Available data for Japan suggest that an even larger share of memory consumed in that country went to computer and office automation equipment production in 1988-- see figure 5. Since the ICE figures do not include captive DRAM manufacturing by IBM, they understate total DRAM consumption in computers.

[10] See CBEMA, **The Information Technology Industry Data Book, 1960-1998**, (Washington: CBEMA) 1989, pp. 102-3. The CBEMA figures appear to exclude small, home personal computers like those typically used as game machines, and count only business-type PCs. The latter appear to be included in PC shipments tallied by some other statistical sources, like Dataquest.

CBEMA's historical annual growth rates for all business computers (micros, minis, and mainframes) are 11 percent, for 1965-71; 47 percent, for 1971-78; 61 percent, for 1978-84; 16 percent, for 1984-87.

scenario put forward by the American Electronics Association.[11]

DARPA appears to assume a fixed 32 Megabit requirement for HDTV receivers over this entire period. It thus shows no growth in memory per unit shipped, for HDTV.

From 1992 to 1997, DARPA has DRAMs consumed per unit computers sold growing at a compound rate of about 22 percent; this drops sharply to about 7 percent over the 1997 to 2002 period, then to 2 percent from 2002 to 2007. However, since the introduction of semiconductor memory into commercial computers in the 1960s, memory consumed per computer has actually grown at a much higher rate, in response to a continuing rapid decline in the cost of semiconductor memory. Figure 6 shows how memory per computer has responded to declines in memory cost since the introduction of semiconductor memory in the mid-1960s, through 1978. The data refer only to mainframe computers.[12]

From 1965 to 1971, memory per mainframe grew at an annual rate of 32 percent per year, from 1971 to 1978 at 25 percent per year, and for the period as a whole, at 29 percent per year. More recent Dataquest data (for all micros, minis, and mainframes combined) imply an annual growth rate in DRAM per computer shipped of about 39 percent over the 1984-87 period.[13] *Since there is no reason to believe that continued improvement in price performance for semiconductor memory driving the increasing memory requirements for computers is about to end--indeed, the current trend for computer operating systems, applications, and graphics is to require vastly increased amounts of memory--* ***this clearly is a major departure of DARPA's assumptions from the actual and prospective historical record.***

For example, DARPA's projections seem to suggest an average configuration of 8.3 megabits (a little under 1 megabyte, with 9 bits to a parity-checked byte[14]*) per computer shipped in 1992. An estimate based on Dataquest figures, would indicate that over 8 megabits of memory per computer, on average, were shipped back in 1987.*[15] *Currently, in 1989, 1 to 2 megabytes is already the standard on even low-end (286 and 386 processor) new model PCs; DRAM used in video display cards typically adds an additional one quarter to one half megabyte or more. The DARPA projection therefore seems significantly off right out of the starting blocks.*

To compare projections for the 1990s, 1987 Dataquest estimates suggest DRAM consumption in computers shipped to the US, Western Europe, and Japan of about 810 million megabits in 1991.[16]

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[11] The data are taken from American Electronics Association, ATV Task Force Economic Impact Team, "High Definition Television (HDTV): Economic Analysis of Impact," (Washington: November 1988), pp. 2-3, 2-5.

[12] This figure is taken from Kenneth Flamm, **Targeting the Computer: Government Support and International Competition**, (Washington: Brookings) 1987, p. 23, where data sources may be found.

[13] This is estimated by taking total bits of DRAM consumed by North American data processing shipments, and dividing by the total shipments of computers to the U.S. market. If the rest of North America had computer shipments that were roughly proportional to U.S. shipments, or were small in relation to U.S. shipments, the growth rate in memory per computer is reasonably accurate.

[14] Eight bits of memory are conventionally used to represent a character or number, and are known as a "byte". An additional bit of memory per byte-- the "parity" bit-- is typically used for error detection.

[15] Dividing Dataquest estimates of DRAM consumed in 1987 North American data processing shipments, by U.S. computer shipments multiplied by 1.1 (Canadian GNP was about 8 percent of US GNP), yields a conservative estimate of 8 megabits of DRAM per computer. To be ultra-conservative, we will assume a 7 megabits per computer starting value for 1987 in our forecast of projected DRAM consumption in computers.

[16] This is estimated by taking 1987 Dataquest forecasts of DRAM sales to data processing equipment manufacturers in the U.S., Western Europe, and Japan in the 1990s, and dividing by Dataquest's projected cost per bit of DRAM memory.

Recent Integrated Circuit Engineering estimates suggest over 1 billion megabits of DRAM will be shipped to the merchant (non-captive) market, worldwide in that same year, 1991.[17] DARPA, by way of contrast, forecasts only 250 million megabits of DRAM consumed worldwide in computers in 1992, about a quarter of what industry sources predict for the previous year! Clearly, if DARPA's computer DRAM consumption line is multiplied by a factor of four, we will get a very different graph.

Fixing the DARPA Graphs

I next propose to correct the obvious problems in DARPA's computer DRAM consumption estimates: to start with a conservative, but more realistic initial value-- 7 megabits per computer, in 1987[18], and use a conservative DRAM per computer consumption growth rate, 20 percent per year, that is at least in the neighborhood of the historical record. This will be superimposed and compared with the original DARPA forecast. It is also useful to contrast the extremely optimistic estimates of HDTV growth DARPA uses with recent AEA projections to see how this alters the DARPA scenario.

Figure 4 superimposes a line starting from a base of 122.5 million megabits of DRAM consumed in 1987,[19] and assuming a 20 percent per year growth in average DRAM usage per computer, on the original DARPA computer DRAM projection. We have followed DARPA in assuming conservative 10 percent annual growth rates for unit computer shipments[20], and have merely used more historically realistic-- but still low-- estimates of 1987 levels, and growth over time, of memory configured with each computer sold. A third line is superimposed to represent HDTV DRAM consumption with the more recent AEA estimates, using the same fixed 32 megabit usage of DRAM per receiver employed by DARPA.

The graph tells a vastly different story with either of these changes. With conservative, but more realistic parameters on memory consumption per computer, even DARPA's extremely optimistic forecast of HDTV growth does not produce an HDTV DRAM market that remotely threaten computers as the primary market for DRAM. And with the-- in my judgement, more realistic but still optimistic-- AEA HDTV sales forecasts, HDTV is a mere drop in a very substantial computer memory bucket.

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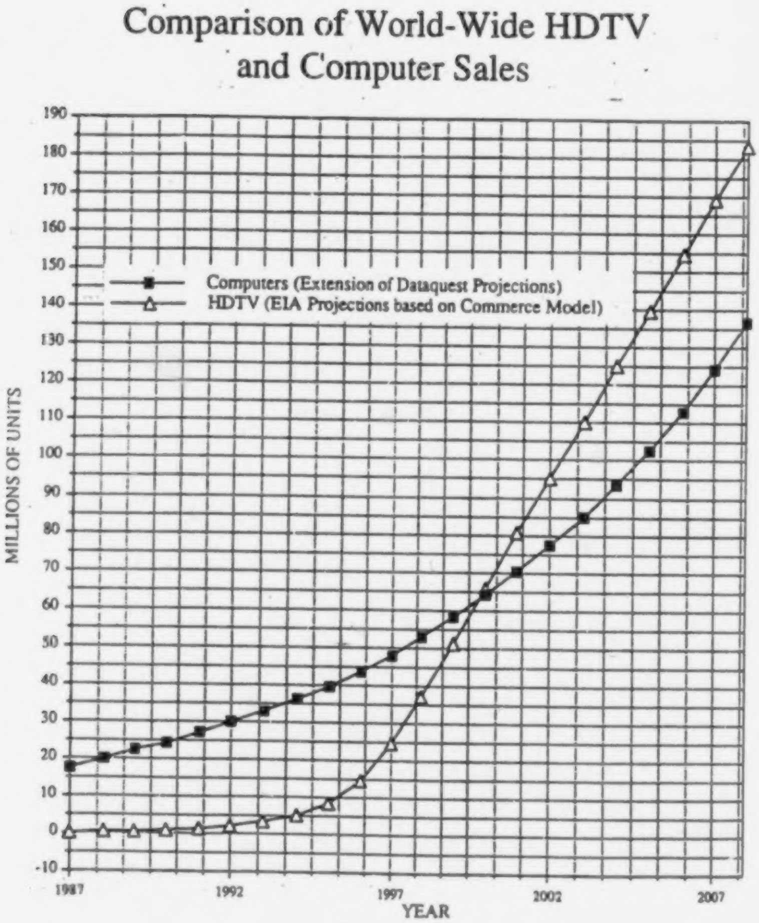
[17] This number is produced by taking ICE's estimates of DRAM shipped in 1991 worldwide, converting it into megabit equivalents, and multiplying by .62. The latter multiple assumes some decline from ICE's estimate that 68 percent of merchant DRAM sales in the U.S. market went into computer and office automation equipment production. It probably understates total DRAM consumption in computers, since IBM's substantial internal production of DRAMs does not appear to be counted.

[18] See footnote 15.

[19] This is produced by multiplying DARPA's estimated 1987 worldwide computer shipments (17.5) by my conservative lower bound of 7 megabits per computer shipped in that year. It is worth noting that this figure is almost identical to an estimate of DRAM consumption in data processing equipment shipped to the U.S., Japan, and Europe for that same year. (See footnote 8.)

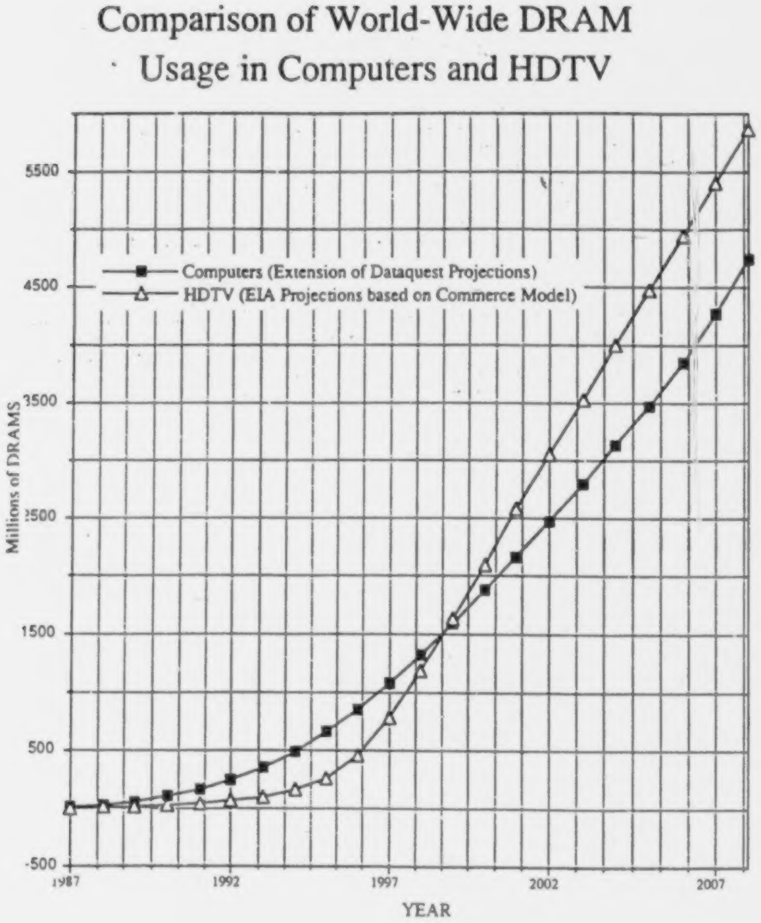
[20] One might argue that growth at historical rates cannot continue over the next two decades, because the U.S. computer market will approach saturation. However, the U.S. market shows no signs of saturation to date; indeed, a primary source of growth has been the ever widening application of cheap computer power to new applications. There is no compelling reason this process should not continue. Furthermore, the rest of the world-- both industrialized countries and the developing world-- lags far behind the United States in intensity of computer use, and just catching up with relative levels of computer usage in the United States could drive computer shipments at very high growth rates.

Figure 1



Comparison of World-Wide HDTV and Computer Sales

Figure 2



Comparison of World-Wide DRAM Usage in Computers and HDTV

Figure 3

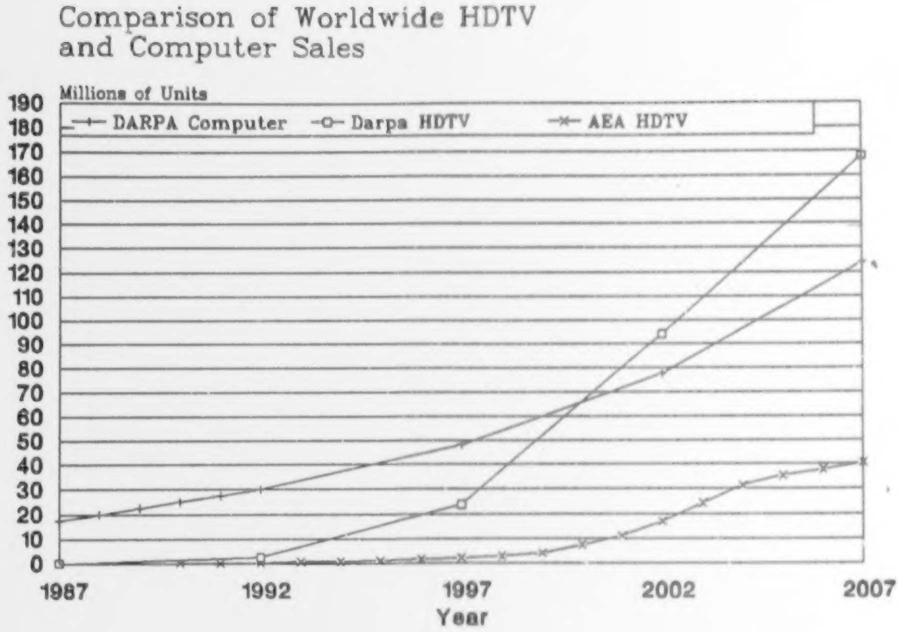

Comparison of Worldwide HDTV
and Computer Sales
Millions of Units
DARPA Computer
Darpa HDTV
AEA HDTV
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
1987
1992
1997
2002
2007
Year

Figure 4

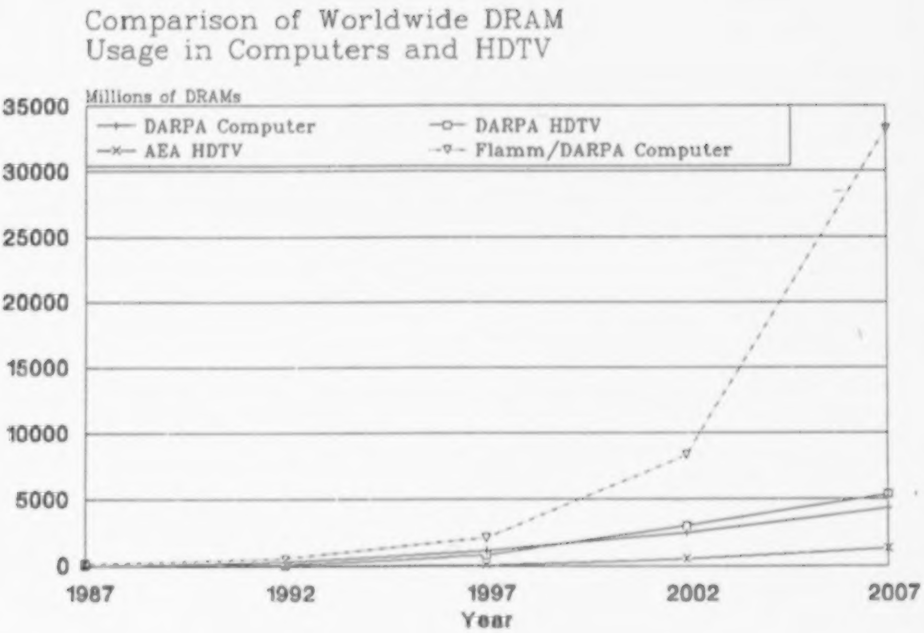
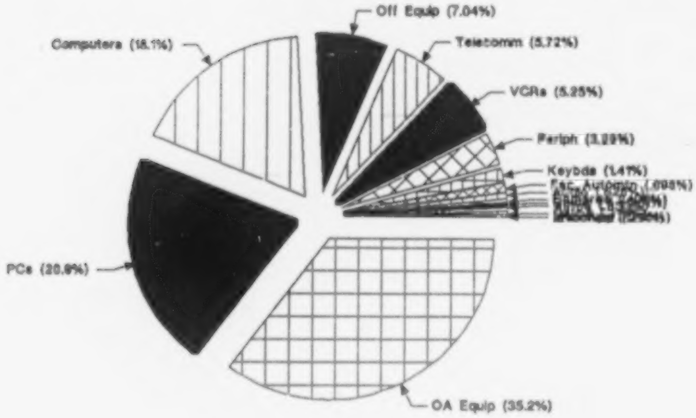

Comparison of Worldwide DRAM
Usage in Computers and HDTV
Millions of DRAMs
35000
30000
25000
20000
15000
10000
5000
0
1987
1992
1997
2002
2007
Year
DARPA Computer
DARPA HDTV
AEA HDTV
Flamm/DARPA Computer

Figure 5

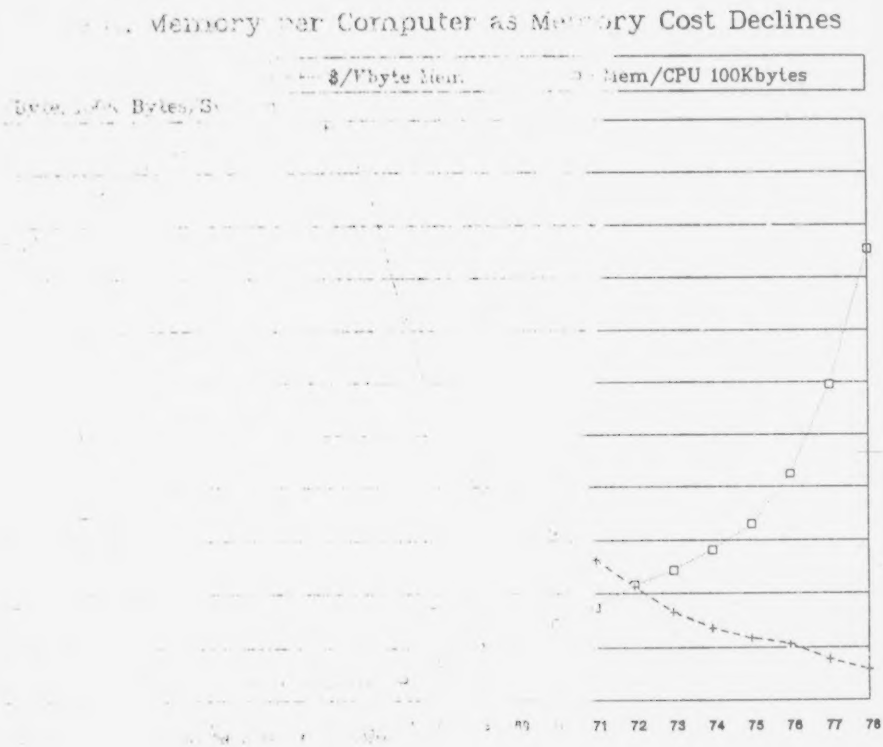
Japanese Semiconductor Consumption
MOS Memory, 1988

By Major User



[illegible]

Figure 6


Memory per Computer as Memory Cost Declines
$/Kbyte Mem.
Mem/CPU 100Kbytes
Bytes, Bytes, $
71
72
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Room 26-341
Massachusetts Institute of Technology
Cambridge, Massachusetts 02139
August 11, 1989

Senator John Glenn
Chairman, Senate Governmental Affairs Committee
Attention: Harry Broadman
Room 304, Dirksen Building
1st and C Streets, N.E.
Washington, D.C. 20510

Dear Senator Glenn,

Thank you for providing this opportunity to comment on the recent testimony and related report of the Congressional Budget Office before your committee relevant to "The scope of the high-definition television market and its implications for competitiveness". I am Professor of Electrical Engineering at the Massachusetts Institute of Technology and am writing as a private citizen.

My comments are directed primarily toward the Congressional Budget Office "Staff Working Papers" of July 1989 prepared on this topic. The degree to which this early report should be amended depends largely upon its objectives. It states that it analyzes "the economic assumptions that underlie widely used forecasts of the HDTV market[1], and evaluates the implications and soundness of these forecasts. The final report will analyze the possible use of federal funds to support industry consortia, such as the one proposed for HDTV." This statement exposes the central problem I see with the present report--sound recommendations regarding government support are desired, but they are to be based principally on market projections, particularly for the HDTV receiver market. The August 1 hearings made clear that the scope of any study promoting sound policy in this area should be far wider than that on which the preliminary working papers were based.

The deficiencies in the July version of the CBO report result because:

1) **First, the "HDTV" market includes much more than consumer television.** The August 1 testimony indicated some of this breadth and that careful projections of this much broader market could be useful.

2) **Secondly, "HDTV technology" is both leading-edge and critical to a broad range of related products** in consumer, industrial, military, telecommunications, and computer markets. I firmly believe the economic significance of this technology is greater than sales projections alone would suggest. This is so because any U.S. competitor manufacturing products dependent upon this or related technologies to even a small degree could

---

[1] These are largely restricted to consumer receivers, only a fraction of the market.

find control over his own profitability at risk; the future markets of such dependent manufacturers far exceed those for pure HDTV products alone.

The mechanisms by which such linkages are affected in the marketplace are varied. First, there are the many forms of tie-in sales. Although tie-in sales are generally barred by U.S. antitrust laws, enforcement of these laws even within the U.S. is difficult because of the subtle ways such tie-ins can be accomplished. When control of the critical element lies overseas, effective discovery can become nearly impossible. Those who believe that foreign firms or cartels with economic power derived from dominance of critical technologies would decline to use that power must bear in mind U.S. antitrust history. This history makes clear that even the largest and finest U.S. corporations often could not resist this temptation despite potentially severe civil and criminal penalties. In addition to tie-in sales there is the opportunity to establish component and therefore market allocation procedures (as allegedly happened recently with DRAMs), placing U.S. firms under the effective partial control of their vertically integrated foreign competitors. There is also the potential for systematic denial of the latest and best technology, a practice I understand has sometimes been implemented for certain advanced machine tools and other critical industrial materiel.

There are other issues which simple market projections do not penetrate. For example, it is important to note that many of the critical HDTV technologies are process intensive. Examples include the manufacture of displays and of special purpose digital signal processing chips. Because process secrets are often extremely difficult and expensive to learn for one's self, and relatively easy to conceal from competitors, a dominant technological power can create enormous entry barriers for competitors whose technology lags behind.

Lagging competitors seeking to catch up must recreate nearly the entire technology development process at enormous risk, expense, and delay, particularly since much knowledge is often derived from observing or repairing millions of units in the field over decades of use. The hurdle cost for U.S. technology reentry in such process-intensive areas can be impossibly high. It is not just a matter of equipment and man hours, it is also a matter of continuity of expertise. Once that expertise and accumulated technological wisdom is lost (when people retire or change fields) it cannot be recovered; this is precisely the sort of expertise that firms do not put in the literature because of its competitive value. I believe the present DARPA HDTV technology initiative will in part help preserve this continuity in U.S. technology, and for this reason could have an economic significance many times greater than its modest size suggests. The hope that dominant foreign firms will always sell their technology cheaply because many U.S. firms did so earlier is not entirely sound here because many of the most critical U.S. technology sales historically were made under government pressure (U.S. antitrust law or foreign industrial policy) or in a multi-seller environment.

3) The linkage between HDTV technology and media is very important. This is an extremely complex area and no simple study could hope to penetrate its full significance. In broad outline the linkage is between control of the technology for communications and influence over the economic entities which generate and distribute that information.

The history of the U.S. consumer electronics industry shows that after we lost audio and hi-fi to foreign firms, we then lost nearly the entire record production and distribution business. I believe the economic advantages of vertical integration made that nearly inevitable. Essentially all the major "U.S." record companies are now foreign-owned, the latest casualty being CBS Records which was sold to Sony. I understand Sony has publicly indicated they plan to continue vertically integrating through media production and distribution, with television and movies presumably being next.

Representative current technology battlegrounds in media are DAT (a technology that could undermine U.S. copyright owners), high definition VCR's (eventually HDTV technology) which can bypass U.S. networks in one of their most profitable product lines (i.e. movies), and HDTV standard setting, which impacts not only the television industry but also movie production. Virtual foreign control of technologies critical to the profitability of U.S. media firms could seriously weaken their independence and bargaining position in these arenas. It is instructive that CBS sold CBS Records to Sony at CBS Record's peak of profitability while under the threat that DAT could seriously devalue its inventory.

The present potential influence of foreign firms on U.S. broadcast networks through advertising and other revenues would be significantly enhanced if the foreign role in production and distribution grew correspondingly. Present U.S. law recognizes the importance of a broadcasting industry independent of foreign influences (critical to a successful democratic society) by restrictions on broadcasting ownership. These U.S. concerns and laws have not yet addressed the growing economic dependence of the networks on decisions of foreign firms. Most other advanced nations have long been much more protective in this area than the U.S.

An important related example of cross benefits between technology control and media participation can be seen in RCA's early success in television, which benefited from the synergism between their technology (e.g. color television) and their control of NBC; their knowledge that they controlled both problems gave them increased confidence their investments would pay off in a timely way (effectively reducing their cost of capital).

4) **There are also problems with material included in the study.** For example, it argues that since U.S. computer companies spent $8.5B on R&D in 1987, HDTV must not be important to computers (because they would have invested in it if it were). A related counter question is: why did the Japanese government begin a $75M effort on flat panel displays when the related Japanese firms are so profitable? Recent history suggests they are doing something right--is this it?

One reason U.S. computer companies have failed to invest heavily in HDTV is that they are sorely pressed in their immediate basic computer business and have sought instead foreign alliances with display firms (e.g.

IBM with a Japanese firm for color LCD displays) because long-term national independence of supply is partly a public good which they, as individual firms, could not afford alone (any more than they would want to buy their own roads or their own national defense). The long-term nature of HDTV investments is also a factor here given the high U.S. cost of capital. The virtue of consortia is that such aggregations more properly link the public character of this good (national industrial independence) with one of its beneficiaries--the entire relevant industry; the U.S. public is another beneficiary, which helps define the proper role of government. Such arguments about public good and U.S. industrial independence are one of the key drivers behind formation of U.S. Memories Inc.

Another key issue is exemplified by the CBO objection that the AEA report does not show how advantages in one area confer advantages in other areas--i.e. the CBO report appears to be placing the burden of proof on industry for the questions posed to CBO. In view of the subsequent diverse good-faith expert testimony on August 1 that HDTV linkages are critically important to the U.S., the burden of any proof to the contrary would appear to lie now with the CBO if it continues to devalue them. I believe that substantial further efforts to understand and quantify such linkages should be undertaken.

I hope these personal observations are helpful and that your inquiry might play a pivotal role in halting and perhaps reversing the present precipitous decline in U.S. technological industrial competitiveness, not only in HDTV, but in other areas as well.

Sincerely yours,

David H. Staelin

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(617)253-3711

PHOTONICS

EXTENDING MAN'S VISION

August 24, 1989

Senator John Glenn
c/o Dr. Harry Broadman
Senate Committee on Governmental Affairs
Room 340
Dirksen Senate Office Building
Washington, DC 20510

Re: Response to Congressional Budget Office
Staff Working Paper on HDTV

Dear Dr. Broadman:

The CBO staff working paper entitled, "The Scope of the High Definition Television Market and its Implications for Competitiveness," does not, as the title implies, analyze the broad scope and implications of HDTV. The July 1989 CBO HDTV staff working paper is primarily based on a narrow and misleading market analysis of three reports: the EIA, AEA, and NTIA (Darby). The main conclusions with regard to the market forecast for HDTV are fundamentally flawed primarily because HDTV is assumed to be similar to NTSC television, except for higher resolution. However, HDTV involves numerous additional technical innovations, and, therefore, will not only be viewed as a dramatic technical advance by the public, but most probably will not even be a CRT technology as assumed in the CBO report projections.

The CBO staff paper correctly states that, "in the mid-1960's, the yearly demand for color television sets grew from 700,000 units to 5 million . . . while the differential between monochrome receivers and color receivers was $840 (in 1988 dollars)." Similarly, the staff paper acknowledges the dramatic growth of VCR's, but then goes on to state that the three market forecasts (EIA, AEA, and NTIA) quoted for HDTV "must necessarily lie at the high end of the range of possible projections," thus discounting the previous acknowledgement of the rather incredible growth of color TV in the mid-1960's. There are no technical reasons offered for this low growth assumption, other than giving several examples of slow consumer acceptance for unrelated products such as microwave ovens. By implication, the report states that HDTV is only marginally superior to IDTV and supports the low market scenario by noting the failure of BETA compared to VHS in the VCR market. To further justify this line of reasoning, the report relies heavily on "experimental evidence" from an MIT study in which the advantages of HDTV were not well perceived at 10 feet for 18" size sets. Yet the same MIT study found that when the audience was seated 3 feet away from 28" monitors, viewers strongly preferred HDTV. Unfortunately, the CBO staff working paper incorrectly interprets these results. What the MIT study really shows is that HDTV only makes sense for large-screen pictures. This is precisely why NHK has designated a minimum screen size of 50" for HDTV. People who have viewed the movie-theater-like quality of large screen HDTV know that the sensory impact for this media format is dramatic.

6967 WALES ROAD • NORTHWOOD OHIO 43619 • TELEPHONE (419) 666-0762 • FAX (419) 666-0785

The dramatic impact of large screen HDTV (i.e., 50" or greater according to NHK) over NTSC is as great as color was over monochrome in the 1960's. The CBO staff paper acknowledges that, "the history of television pictures makes it clear that consumers will pay substantial amounts for what they perceive as enhancements." Why is it then that NTSC projection television currently enjoys only a niche market? The answer is that at a viewing distance of 10 feet, the very pronounced horizontal lines associated with low resolution NTSC are objectionable. However, the horizontal lines virtually disappear in a similar size HDTV picture. This, then, combined with a vastly expanded color palette, the elimination of picture defects via digital processing, and the more cinema-like horizontal aspect ratio of HDTV will make this new TV media a consumer hit, as the Japanese are currently demonstrating and investing.

Realistic market projections for large screen HDTV must take into account flat-panel display technology. In May of 1989, Photonics Technology demonstrated a 17" flat-panel color video monitor. Photonics has been producing 60" high-resolution flat-panel monochrome video monitors since 1986. Photonics has proposed to deliver to DARPA in 1991 a low-cost, large screen, flat-panel color monitor that is HDTV compatible and can hang on the wall like a picture. This is five years earlier than the 1996 goal of a 40" flat-panel display from Japan's MITI Giant Electronics Project! Photonics believes that the introduction of large screen flat-panel HDTV will create a U.S. market on the order of $20 billion before the end of the 1990's. This is 10 years before that predicted by the Darby report which the CBO has discounted as being unrealistically optimistic. If DARPA is funded to properly support HDTV, the U.S. can actually develop large flat screen technology years before either the Japanese or Europeans and get a jump start on the world market. **The CBO paper apparently does not discuss these possibilities because it is unaware of the real possibilities that DARPA has uncovered in its first round of funded HDTV research.**

The near-term, high-growth market predicted above for large-area, flat-panel HDTV is consistent both with Japanese predictions and the fact that approximately 15 Japanese companies are presently pursuing flat-panel HDTV technology. The CBO paper makes light of this incredibly large-scale effort by the Japanese who have shown themselves to be rather astute in focusing on strategically important consumer product markets.

In addition to the above, the spin-off economic consequences for HDTV flat-panel technology are in total even more important than HDTV itself. These markets include automotive displays, laptop computers, engineering workstations, medical imaging, video games, industrial imaging, CAD/CAM, graphics and video simulators, scientific instrumentation, industrial controls, radar, air traffic control, telecommunications, navigation, personnel training, military command and control, etc. All of these potential flat-panel HDTV-type markets would also require high volume quantities of DRAM semiconductor and other electronics material to support the flat-panel displays. Since DRAM's are considered the leading edge semiconductor technology in terms of process development and fabrication, it is critical that the U.S. re-establish itself in this market. Recent attempts to recapture this technology through the proposed consortium, U.S. Memories, Inc., will be dealt a serious setback if HDTV becomes a Japanese or European dominated industry. The CBO paper even acknowledges this fact by stating that foreign HDTV receivers manufactured in the U.S. will import 100% of their electronic components (see footnote 21). On this point, the total value for electronic components has been grossly underestimated by the CBO report which estimates a range of 6 to 12 percent (footnote 30). For flat-panel monitors, the range is at least triple this value on a volume almost ten times that predicted by the CBO. In this regard, it is noted that unlike CRT's, flat-panel displays are matrix addressed and digital in nature, as even the CBO paper points out: "digital television receivers are voracious consumers of digital signal processors."

The CBO staff paper implies it is unlikely that either HDTV or the DARPA grants for R&D on flat screen displays will drive this (i.e., flat-panel) technology." However, the undeniable fact is that the flat-panel business in the U.S. is virtually a 100% small business enterprise. The flat-panel companies have not been able to attract the necessary capital to build low-cost, high-volume manufacturing facilities for laptop computers because it is not a high profit business. However, development of large-size HDTV flat-panel technology opens up numerous high margin markets, especially for vertically integrated companies. In other words, a company that makes large-area HDTV flat-panel displays, can manufacture the entire receiver and thereby compound profitability. In addition, being able to manufacture high-volume, large size HDTV flat-panel monitors will allow the same manufacturer to produce lower cost small displays on a large size production line, thereby opening up new flat-panel markets. It must be stated emphatically that currently there is no significant R&D money available to flat-panel U.S. manufacturers other than the DARPA initiative. Thus, getting into such markets as laptop displays is a chicken-and-egg problem for which the only satisfactory answer for a small company is success in the DARPA HDTV initiative.

The DARPA HDTV initiative provides the opportunity for innovative U.S. flat-panel manufacturers to technically leap-frog the Japanese by perhaps five years. The country that manufactures the most advanced flat-panel displays will immediately gain an important advantage in producing all other products dependent upon advanced display technology, including automotive displays, CAD/CAM, laptop computers, engineering workstations, medical and scientific instrumentation, radar, graphics and video simulators, air traffic control monitors, navigation and telecommunications equipment, etc.

Finally, it is important to note that the CBO assumption that foreign HDTV technology will be manufactured in the U.S. could be totally in error. The CBO assertion assumes that HDTV will be based on CRT technology. If the preferred HDTV technology is a light weight, flat-panel monitor, then the entire package may very well be shipped to the U.S. as a single integrated unit.

Very truly yours,

Peter S. Friedman

Dr. Peter S. Friedman
Executive Vice President

MCC
MICROELECTRONICS AND
COMPUTER TECHNOLOGY
CORPORATION

3500 WEST BALCONES CENTER DRIVE
AUSTIN, TEXAS 78759 6509
(512) 343 0978

July 31, 1989

The Honorable John Glenn
Chairman, Senate Committee on
Governmental Affairs
SD-340 Dirksen Senate Office Building
Washington, D.C. 20510

Dear Mr. Chairman:

This letter is in response to a biased and dangerously misleading study of the implications of high definition television technologies prepared at the request of your committee by the Congressional Budget Office. We received this study from industry colleagues who are disturbed by the limited view it takes and the possibility of it being used to obscure serious consideration of a set of very important technology developments. We very much share those concerns and we wish to comment on the technologies involved from our perspective as the leading U.S. research consortium in the broad areas of microelectronics and computing. We would appreciate your including these comments in the record.

The draft CBO study that we saw (and we understand that the final version will not be much different) was a sterile exercise in quibbling over the numbers in someone else's study. In all the econometrics, there was very little understanding of the nature of the technologies being developed in Japan and Europe under the rubric "HDTV" or of the implications of allowing the lead in those technologies to pass by default to foreign manufacturers.

A KEY, GENERIC TECHNOLOGY

From our perspective, "HDTV" goes far beyond TV sets. We see a series of technologies -- for high-resolution display, image processing and storage, multi-media services, and the transmission and production of such information -- being developed which will find application not only in "TVs" but across the electronics and computing industries. It would be far better to understand these technologies as multi-function, multi-media processing technologies. They will probably be led by "HDTV" consumer applications in the 1990s, but they are themselves generic driver technologies which will find common application in many fields.

The CBO study missed this point entirely. In looking narrowly at just a substitute for the TV sets people now have in their homes, the CBO study simply cast doubts, first on the rate of substitution of HDTV for TV, and then on the "backward linkage" of HDTV to the semiconductor industry. We think the CBO study made some totally unwarranted assumptions about the economics of TV production, and arrived at an unreasonably low estimate of the consumption of semiconductors in consumer-oriented HDTV sets, but we will leave the response on these point to others. We would note here, however, that the CBO's doubts and theoretics aside, Japanese companies seem to believe that HDTVs are going to consume huge amounts of semiconductors: Both Sony and Matsushita are setting up major new DRAM production facilities in anticipation of HDTV-related internal demand (see *Nihon Kogyo Shimbun* (Japan Industrial Daily), 7/6/89). We would also note that HDTV systems, which place a premium on processing speeds, are likely to consume a large volume of SRAMs as well as DRAMs and processing chips.

Our particular concern is with the other technology implications of HDTV. Among the many technology development organizations in the United States, MCC has perhaps the best perspective of what key, generic technologies are and how they should be developed. Our consortium, though it is often misconstrued as a "fifth generation" computer project, is owned and almost wholly funded by a diverse set of private companies who have charged us with developing and transferring state-of-the-art technologies in five fields: advanced computing, computer-aided design for very-large-scale integrated circuits, software design, the packaging and interconnect of electronic systems, and the electronic applications of high-temperature superconductivity. Our 19 shareholder companies range from computer manufacturers such as the Digital Equipment Corporation and NCR, to semiconductor manufacturers like AMD and National Semiconductor, to materials companies such as 3M, to major aerospace manufacturers, to other diversified companies such as Kodak and Motorola. We also have 16 Associate members, including such diverse organizations as Apple Computer, Dupont, LTV, the National Security Agency, Symbolics, and Sun Microsystems. Recently, we have decided to accept research contracts from government organizations such as DARPA, and we are pioneering a new form of technology transfer between the defense and civilian sectors by developing defense-related technologies in our broad-based consortium.

In designing research programs to meet the needs of our diverse set of customers, MCC has had to select key, generic technologies of interest to many participants. In our Packaging/Interconnect program, for example, we are creating new ways of putting together electronic systems for applications in everything from cameras to aircraft to supercomputers. We have five years of experience at this task and we have succeeded in delivering an impressive set of such technologies. In our view, "HDTV" is the example *par excellence* of a key, generic technology.

Indeed, it was because of our experience, and our focus on researching technologies with broad application, that we ourselves became involved in HDTV and submitted a bid in response to the DARPA Broad Agency Announcement. When we put together our response, we organized a bidding consortium which included the Hughes Aircraft Company, Harris Corporation, Hughes Network Systems, LTV, the Power Electronics Application Center, Symbolics, National Semiconductor, Planar Systems, Fiberview, Bellcore, the New York Institute of Technology and Kodak. We later had expressions of interest in our HDTV consortium from several of our other members, including computer makers Apple and Sun. None of these organizations makes TV sets now, but they are all concerned that the lead in the multi-function, multi-media processing technology being called HDTV does not pass to Japan and Europe for lack of an American effort. The fact that these companies responded to our call for a consortium, and were willing to contribute component technologies for the demonstration system required in the DARPA BAA, is good evidence that "HDTV" is not just TV sets.

ECONOMIES OF SCOPE

The thing we at MCC most want the Committee to understand are the implications of HDTV resulting from the "economies of scope" that this key, generic technology will create. Economies of scope mean that production in one area yield an economic advantage in others, especially due to the use of common technologies. Economies of scope relate in critical strategic ways to economies of scale. If foreign companies are allowed to dominate the flywheel application areas of HDTV, such as home entertainment, the scale economies they achieve in producing these systems will allow them to make mincemeat of American companies in other areas. It is important to remember in this regard that our Japanese, and to a lesser extent our European, competitors are vertically- and horizontally-integrated companies which are designed for the achievement of economies of scope. They not only can translate a scale advantage from one area into a technology advantage in another, they have in fact done so many times, with devastating results for American industries. The Congress must therefore consider, in addition to everything else, the effect that losing this industry by default will have not just in consumer electronics and semiconductors, but in a host of related industries.

The economies of scope in HDTV have several dimensions.

1. INTEROPERABLE COMPONENTS

First, "HDTV" technologies will be used not only in home "TV sets" but in everything from defense systems to computer displays to computer-aided design systems. Whole parts of HDTV systems, such as displays or digital signal processing chips, will be interoperable between various applications. Japanese manufacturers have already begun incorporating the LCD technology developed in small TV sets into computer displays. Lap-top computers featuring color LCD screens have been featured at recent business electronics shows, and the same technology has been seen in TV screens at consumer electronics shows. The major Japanese electronics companies are clearly driving for a synergistic cycle of improvement of not only LCD technology, but other display technologies and all the processing technologies which can be used for multi-media systems. They are being supported by their government in their attempts to make yet further improvements (see below). Computer interface technologies, such as displays, have been the key success factors for individual firms at several stages of the development of the U.S. computer industry. There is a very real danger of further inroads into the U.S. computer market by Japanese manufacturers if they are allowed to dominate display technology.

Because of the broad applications of HDTV technology, it is entirely appropriate that DARPA fund research in this area. High-resolution displays and display processors are vital to modern defense systems. The technology component of U.S. defense systems has done nothing but increase in the past, and it will continue to do so in the future. As defense systems become more sophisticated, interface technologies, which allow humans to control and operate those systems, become system critical. The Defense Department must be concerned not only with having the best possible interface technology, but also with the American manufacturing base for such components. There is no question that Japanese companies are going to achieve significant scale economies in displays, for example. If there is no U.S. industry with similar scale economies, another key defense-related technology will soon pass into foreign hands.

Computer-aided design systems remain an area of strong U.S. competitiveness, but such systems are also critically dependant on display capabilities. If Japanese manufacturers are allowed to dominate HDTV display and display processing, it will be relatively easy for them to translate that strength into a challenge to the U.S. CAD systems industry, which is already using small quantities of high resolution displays.

2. TECHNOLOGY MERGING

The second way in which HDTV technologies will create economies of scope is through their use in integrated systems which merge the functions of several different existing products. The "TV set" in one's home is going to pack enough processing power and machine memory to serve as a stand-alone computer or as a node on a whole host of networks, which will provide services ranging from videotext to movie rentals to TV telephone systems. The merging of product technologies will lead to a merging of the products themselves. Japanese companies are not producing HDTV sets in quantity at the moment, but they are producing "home computers" that run standard PC application software as well as games and telecommunications applications. Fujitsu's "FM Towns" series of 16-bit PCs is a good example of this technology. It will be technologically simple to attach HDTV-standard display technology to these systems and make them TV/computers. When this happens, U.S. PC and workstation makers will be in for a new and very dangerous threat in a substantial portion of their market. One of the hottest research topics for Japanese electronics makers in the past two years has been multi-media database systems, in which moving pictures, still pictures, voice and sound data, and text data from a variety of sources can all be accessed and processed on one machine, perhaps attached to a network. NEC and Mitsubishi Electric are particularly active in this technology, which is destined to become the software brains of the TV/computer.

The Japanese Ministry of International Trade and Industry is making sure that all the major electronics manufacturers advance in multi-media technology, and that their systems will be interoperable, by funding a "large-scale project" for interoperable database systems with multi-media capability. MITI is spending ¥15 billion ($100 million) from 1985 to 1991 in this project.

This merging of TV and computing technologies is by no means confined to home applications. Telecommuting is already becoming a reality, and it is well known in the computer industry that people will pay a premium for a display they have to look at all day long. The TV/computer will also be a critical component of television conferencing systems, an area in which Japanese manufacturers are moving very aggressively. In the first six months of this year, NEC, Hitachi, Matsushita and Fujitsu all announced new TV conferencing systems, several of them using the integrated services digital network (ISDN) being created nationwide in Japan by the Nippon Telephone and Telegraph company. These systems can transmit all forms of TV, audio, text and graphical information, and depend critically on high resolution display and display processing capabilities.

Business-use personal computers will be part of this capability. Fujitsu, for example, recently announced a 16-bit personal computer called FMR-50VT, which can show color pictures and be used with on the ISDN network. Image data can be obtained over the network or from video cameras and video recorders. Up to 16.7 million colors can be displayed and the system can also be used as a videotex terminal.

3. TECHNOLOGY PLATFORM

Japanese and European manufacturers are also planning to make HDTV systems the platform for a wide range of peripheral devices, such a printers, copying machines, cameras, and VTRs. Japanese companies are now developing excellent technology for full-color printing. They already have technology for copiers that can accept a variety of image sources. Canon, for example, announced in late May that it has developed an improved version of its full-color copying machine and a series of interface modules through which the printer can accept input images from TVs (NTSC, for now), computers, VTR players and cameras, and electronic still cameras. Canon has been selling the copying machine for two years, in competition with a similar machine from Ricoh. Canon's improved version has 256 tones per color, resolution of 400 dots per inch, and standard memory of 48 Mbits for images and 16 Mbits for text, expandable to a total of 192 Mbits. Like the previous version, it can also function as a simple copier, with image sources scanned in. In the new version, images from all sources can be assembled, edited and processed with an attached PC before printing.

It is important to note in this connection that the estimates of semiconductor consumption in the CBO study did not include consumption in all the peripherals that will be used in different HDTV systems. The Japanese already call VTR machines "IC hogs". Any system processing image data is going to be memory-intensive. Put several of these systems together and memory requirements will expand exponentially.

4. UNDERLYING TECHNOLOGIES

MCC is most concerned about the fourth way in which HDTV technologies will create economies of scope, which is through the common application and development of the underlying technologies, as opposed to the components, that will be used in these systems. Electronic packaging (where MCC is a world leader), new algorithms for digital signal processing, and parallel processing are examples of these underlying technologies. Japanese consumer electronics manufacturers already use packaging technology in their hand-held LCD TVs which is as sophisticated at that being used in advanced U.S. defense systems. The fact that they are learning to mass apply these technologies in low cost ways holds ominous implications for future U.S. defense capabilities. Manufacturing process technologies, already a strong factor in Japanese competitiveness, will receive yet another boost from HDTV development.

Parallel processing, an important branch of computer science research which has led to the development of some of the most innovative U.S. companies, will also be critically affected by HDTV development, since it is especially well-suited to certain forms of image processing. Japanese manufacturers are aiming to mass apply parallel processing in the new digital imaging technologies being driven by "HDTV." Matsushita's Information Systems Laboratory, for example, has already developed a high-speed three-dimensional image generator, called the Shaded Image Generator 2, which is compatible with HDTV standards. The system connects 36 32-bit processors in parallel with the VME bus, and can generate ten 3-D frames per second at a resolution of 512 X 480 pixels. With an HDTV-standard frame memory, it can also display pictures at a 1,920 X 1,035 resolution in 16.7 million colors. Various new algorithms are used for different types of image generation. Hitachi has also developed a three-dimensional parallel processing image generator for HDTV. The Japan Computer Corporation has developed an image processing computer which uses five R-3000 RISC processors in a pipeline architecture and achieves speeds of 50 MFLOPS (million floating operations per second).

These three example technologies -- packaging, parallel processing, and image processing algorithms -- are among the most important underlying technologies in supercomputers, computer graphics and computer-aided design, all areas in which the United States will be challenged if the technologies are mass applied overseas and not here.

5. FORWARD LINKAGES

Finally, those companies which control the flywheel applications of HDTV will in all likelihood be the ones to capitalize on whatever "forward-linked" (or successor) technology applications arise from HDTV. Some of these applications can be seen now; others will become visible only with time and experience (which we hope will be in the U.S., as well as Japan and Europe). European governments, which are pouring $300 million into EUREKA Project 95 (for HDTV prototype systems and standards) expect that the applications of HDTV in other systems such as traffic control systems, plant monitoring, long distance diagnosis and automotive on-board navigation systems will be "endless."

The Japanese Government obviously believes so too, since it is investing large sums of money into at least three types of application development schemes -- "Hi-Vision Cities," "teletopia," and "new media communities." The first scheme is funded by the Ministry of Posts and Telecommunications, which has already designated fourteen "HDTV model cities," which will spend approximately $100 million to develop various application systems. The teletopia and new media communities are funded by the Japan Key Technology Center (see below) and each aim at proving a particular multi-media application of advanced telecommunications technology. Approximately 35 of these projects have been funded so far. Each will spend in the neighborhood of $5 million of national government money, to be matched in varying degrees by local government funds and private sector participation.

Beyond the forward linkage to large systems, HDTV technologies would appear to hold considerable promise for advancing the state-of-the-art in computer interface technologies. "Visualization" -- for scientific problem solving, design and other applications -- has become an important computer technology. It depends critically on improvements to display and display processing capabilities. Beyond visualization, "artificial reality" is emerging as an important research topic. Advanced digital processing and display technologies are already applied to simulation systems, such as pilot training systems, and HDTV technology will carry these capabilities several steps further. Simulation systems, in turn, will evolve into a total environment (an "artificial reality") in which the participant will be unable to distinguish between the artificial and the real. With HDTV panels around a room, for example, and a considerable amount of processing and memory capability, whole environments -- such as battlefields, other planets, sports events, or scientific conditions -- can be created. Artificial reality is still in the provenance of science fiction, but the day is not too far off when these systems will be used. By forfeiting the underlying technologies to foreign competitors, the United States could very well squander its present lead in simulation and other advanced applications of man-machine interface technology.

The CBO study considered none of the strategic implications arising from the economies of scope inherent in "HDTV." We believe the committee must redress this imbalance at the earliest possible opportunity by requiring the CBO or some other appropriate organization to fully consider the implications of HDTV in all the high technology areas it will affect

JAPANESE AND EUROPEAN COMMITMENT TO THIS KEY TECHNOLOGY

This is an especially urgent task, since our competitors overseas fully appreciate, and are now working now to capitalize on, the economies of scope made possible by "HDTV." The European effort in EUREKA Project 95 has been noted. Japanese government and industry, as is well known by now, have already invested large sums (estimates range from $750 million to $1.5 billion) in HDTV technology development. They will invest yet more as these technologies move into production. Japan's national broadcast company, NHK, has played a lead role in setting the pace of HDTV development, but it is important to understand that the Japanese are by no means locked into the MUSE standard for direct satellite analog broadcasts being promoted by NHK. Japanese companies, working with NTT and other service companies, are developing digital capabilities for all aspects of HDTV production, transmission and processing.

The Japanese government, moreover, has recently begun three new projects designed explicitly for realizing the technological economies of scope inherent in "HDTV." All three projects are being funded as R & D consortia by the Japan Key Technology Center (KTC), a government research funding organization under the joint jurisdiction of MITI and the

Ministry of Posts and Telecommunications. KTC has funded 70 R & D consortia in the past three years. About half of them are the teletopia and new media community projects mentioned above. The others are larger, more ambitious projects for the development of "key" technologies, i.e. generic technologies of use to many industries important to Japan's economic future. The selection of three projects for HDTV- related development by this major Japanese research funding institution supports our view that HDTV technologies are key, generic technologies.

The first project is the High Vision Technology Laboratory, which was created this past April by the KTC, NEC, Seiko-Epson and Meitek. This consortium will develop LCD display technologies and some of the processing capabilities to support the display for high definition flat panel screens to be used in home TV sets, computer displays and other applications. Plans call for investing $75 million over four years in the project itself, but participating companies will invest much more in the development of process equipment.

The second project is not much discussed in connection with HDTV, but is clearly related. The Graphics Communications Technology Corporation, another KTC-supported consortium, will develop algorithms for the processing of three-dimensional and other image data; for the use of image processing algorithms in communications systems; and for the development of subsystems used in the processing of image data. This technology, which is basically computer technology, points to the merging of TVs and computers. It will be applied to TV telephone systems, factory automation, education, publishing, environmental sensing and measurement, CAD/CAM, and several other areas. No budget figure for the four-year term of research is publicly available, but the project spent about $5 million in its first year of operation.

The third "HDTV" project, funded by the Key Technology Center and 17 companies beginning this year, is for what the Japanese are calling "giant electronics." GTC, as the consortium will be called, will develop technologies for the production of high-density integrated circuits over a large area, i.e. up to a 40" diagonal surface, on glass and other substrates. This project will run for seven years, and there are conflicting reports on the budget, ranging from a minimum of $20 million to upwards of $90 million. We suspect that the latter figure most accurately reflects the total government and private spending that will be devoted to this project. "Giant electronics" displays will be useful in all the major display technologies -- LCD, plasma displays, and thin-film transistors -- being developed for HDTV systems. This technology will have many other applications, however, in fields ranging from photocopiers to touch panel screens to solar batteries. These applications and the technologies to be developed are presented in Exhibit 1 (Plan for the Giant Electronics Project).

The Japanese, and the Europeans, are pursuing a broad-based strategy that takes into account both the economies of scope that will be created in "HDTV" and sensible ways to accelerate the virtuous cycle of HDTV development. The CBO study cast doubt on how rapidly the consumer HDTV market would grow. Well, everyone should realize that it is not going to simply grow by itself. HDTV is a complex set of technologies which in their consumer-oriented applications require the development of a large supporting infrastructure. In both Japan and in Europe, therefore, government and industry, are creating test beds for HDTV development, working hard to find industrial and other applications that will stimulate the development of HDTV production capacity and drive down costs, and pursuing a broad-based research agenda that will encourage the operation of economies of scope.

The CBO, judging by the content and tone of their report, would be content to wait until an HDTV industry first grew by itself and then accommodated itself to economic theory. Our foreign competitors, on the other hand, are getting on with the difficult job of bringing new technologies to fruition. They have done this before in other industries, much to our later regret, and they are doing so right now in HDTV.

The CBO report dwelled on some of the uncertainties and risks associated with the development of consumer HDTV systems. The future is indeed uncertain, and real research is inherently risky. There is a far greater risk for the United States, however, if we are left behind in HDTV by ambitious foreign competitors which are cooperating with each other to realize the potential of this new key technology.

We at MCC respectfully request that the Committee give this technology a more balanced hearing and urge your full support for the HDTV research plans put forward by DARPA and other federal agencies.

Sincerely,

Barry Whalen, PhD.
Senior Vice President
for Plans and Programs

Mark Eaton
Director, International and
Associated Programs

Exhibit 1. Plan for Giant Electronics project (ILO translation)

INCREASING NEED FOR LARGER AREA ELEMENTS

Due to the rapid increase in the volume of information processed in modern society, there is a growing demand for the development of larger-area circuit elements. Thus, while the current focus of conventional electronics technologies is miniaturization and integration, the development of giant electronic systems is gaining momentum as well.

There is increasing demand for

- **(1) Larger area image information input-output devices**
- **(2) Larger area for information processing and transmission devices**
- **(3) Larger area and more compact (i.e., less thick) devices for other applications as well**

I. Subjects for element technology development

In order to develop large-area circuit elements, many breakthroughs in basic technical subjects will be required, especially in the fields of electronics, printing, organic chemistry, and inorganic chemistry. Target areas for development include the following:

- (1) large-area high precision glass substrate technology (high flatness, high heat resistance, nonalkalinity, and distortion resistance
- (2) large-area high precision think film technology (highly functional semiconductor film, highly functional oriented film
- (3) large-area high precision patterning technology (high precision mask, high precision exposure, high precision printing)
- (4) highly functional liquid crystal material technology (low viscosity, high specific resistance, insensitive sharpness)
- (5) large-area high precision assembly technology (super-large, thin substrate pasting; high-precision liquid crystal injection; thin, flat light source; high precision shield

II. Technological areas which will benefit from the Giant Electronics Project

- (1) Super-high precision glass substrate technology (super-high density optical disk, super-high precision glass)
- (2) Super-high functional non-defective thin film technology (optical recording thin film, super-thin insulating film)
- (3) Super-high precision patterning technology (precision electronic parts manufacturing by print method)
- (4) Super-high functional liquid crystal material technology (liquid crystal with high response speed)
- (5) Super-high precision assembly technology (large-area glass paste technology, COG [chip-on-glass] technology)

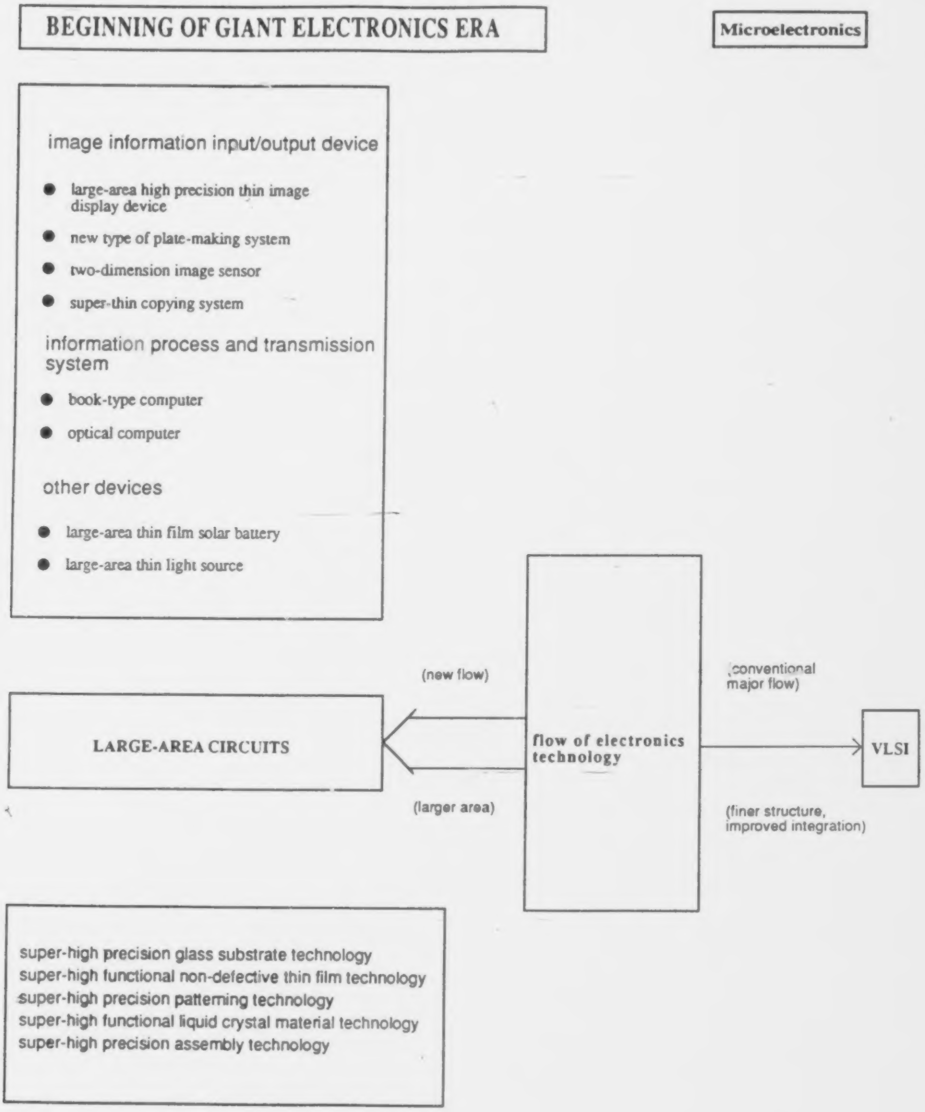
III. Applications of large-area circuits

- (1) Image information input/output devices
  1. large-area high-precision thin image display device
  2. new type of optical plate-making system
  3. two-dimensional image sensor
  4. super-thin copying system
- (2) Information processing and transmission devices
  1. book-type computer
  2. optical computer
- (3) Other various devices
  1. large-area thin film solar battery
  2. large-area thin flat light source

IV. Contribution to industry and society

- (1) Contribution to global society
- (2) Expansion in domestic consumption
- (3) Contribution to life and culture

Exhibit 1. Plan for Giant Electronics project (continued) (ILO translation)


BEGINNING OF GIANT ELECTRONICS ERA
Microelectronics
image information input/output device
● large-area high precision thin image display device
● new type of plate-making system
● two-dimension image sensor
● super-thin copying system
information process and transmission system
● book-type computer
● optical computer
other devices
● large-area thin film solar battery
● large-area thin light source
(new flow)
(conventional major flow)
LARGE-AREA CIRCUITS
flow of electronics technology
VLSI
(larger area)
(finer structure, improved integration)
super-high precision glass substrate technology
super-high functional non-defective thin film technology
super-high precision patterning technology
super-high functional liquid crystal material technology
super-high precision assembly technology

Source:MITI

Semiconductor Equipment and Materials International

SEMI

TESTIMONY OF SEMICONDUCTOR EQUIPMENT AND MATERIALS INTERNATIONAL (SEMI)

Before the

GOVERNMENTAL AFFAIRS COMMITTEE

UNITED STATES SENATE

on

HIGH DEFINITION TELEVISION

August 1, 1989

2000 L Street, N.W., Suite 200, Washington, D.C. 20036, U.S.A., 202 457 9584, FAX 202 659 8534

Mr. Chairman and members of the Committee, we are honored to have this opportunity to discuss the implications of HDTV on the competitive and economic position of the United States.

Semiconductor Equipment and Materials International (SEMI) is the trade association representing the U.S. semiconductor equipment and materials industry. SEMI has 850 U.S. members whose products consist of a full range of advanced tools and materials necessary for semiconductor fabrication.

Many companies in our industry have decided to adapt their equipment to fit the needs of a growing flat panel market. As a result the existence of a U.S. flat panel display industry has become important to the growth of many of our member companies.

Because flat panel displays are an important component of all high resolution video applications including HDTV, we are extremely concerned by the absence of a U.S. high definition television manufacturing initiative. SEMI believes that U.S. public policy makers have not recognized the full implications of HDTV for U.S. electronics manufacturers. We believe the CBO report entitled: "The Scope of the High Definition Television Market and Its Implications for Competitiveness" is indicative of this. The report focuses too narrowly on the uncertain nature of the market for television sets and does not address the variety of technologies affected by the HDTV umbrella.

As the production of flat panel displays is the primary concern of our industry, and as it was not addressed in detail by CBO, it is that subject on which we will focus this testimony. In particular we will demonstrate the existence of a U.S. base for production of flat panel displays, the importance of flat panel technology to the semiconductor equipment industry, and finally the need for a viable, healthy, flat panel display industry in this country.

The processes used to manufacture critical flat panel display components is similar to the processes used to manufacture semiconductors. In fact, of the approximately 30 pieces of equipment and materials needed to build an active matrix liquid crystal display (AMLCD), 28 are produced in some form by semiconductor equipment and material vendors (see table 1).

The flat panel market will also offer our industry the opportunity to diversify and thus counterbalance the effects of the volatile semiconductor business. Presently the U.S. semiconductor equipment and materials industry is in the midst of serious restructuring and consolidation. The cost of staying competitive is exorbitant and to some too high, as demonstrated by the divestiture of Perkin Elmer's semiconductor division, the sale of Monsanto, and the recent acquisition by Sony of MRC, a leading sputtering company.

The flat panel display market offers a partial solution to this situation. By increasing economies of scale and diversifying into a market with different growth cycles, the U.S. SEM producers would be financially better situated to weather the downturns so characteristic of the semiconductor industry. In sum the outcome would be a stronger semiconductor equipment and materials industry.

Finally, we believe that it is necessary to analyze the importance of a having a flat panel manufacturing base in this country. The absence of an indigenous flat panel industry will greatly hamper the competitiveness of our still dominant computer companies. The increasing reliance on laptops, the picture quality of the flat panel, and its size and weight advantage, are characteristics which indicate that flat panels will replace the generic cathode ray tubes (CRTs) as the standard computer screen.

The significance of this predicted change is important. Unlike the present monitors which are relatively low technology and can be purchased from a number of sources, the flat panels will most likely be made available solely from foreign suppliers, mainly the Japanese. The result will be that U.S. systems houses like DEC, Hewlett Packard, Sun Microsytems, UNISYS, etc. will be dependent on foreign screen suppliers who are often closely linked with their competitors.

Another reason for supporting the creation of a domestic flat panel industry is its importance to the defense industrial base. Flat panel screens have numerous uses in the military from map rooms, to cockpits, and mobile control centers. In addition they will not explode upon impact and if one pixel is disabled the rest of the screen will not be impaired.

Today we have focused specifically upon the flat panel display aspect of HDTV. We believe the applications are numerous, and will have a substantial impact upon the U.S. electronics infrastructure. There are other technological considerations encompassed by HDTV television technology, such as the potential market for memory chips and advances in receiver technology, which are better answered by their specific industry sectors. However, what is critical is that the technologies be analyzed under their own merit and that their significance not be judged by the market for a television. The task is a large one, but the importance of this technology to the U.S. demands that it be met.

Attached for your information is a copy of our white paper which will provide you with further background on the subject of flat panel displays.

Thank you for your time.

Table 1

AMLCD Production Requirements

Requirement	SEM	non-SEM
Glass substrates	X	
Backlighting source		X
Filters/polarizers		X
Substrate clean, dry equipment	X	
Photoresist material	X	
Photoresist coating equipment	X	
Photoresist pre-bake equipment	X	
Photolithography exposure tools	X	
Photoresist development equipment	X	
Photoresist hard-bake equipment	X	
Thin film etching equipment	X	
Thin film evaporation/sputtering tools	X	
Chemical vapor deposition (CVD) equipment	X	
Laser annealing/materials conversion tools	X	
Metals/gases for sputtering/CVD	X	
Materials handling equipment (whole line)	X	
Inspection tools	X	
In-process circuit test tools	X	
Repair tools	X	
Assembly tools	X	
Automatic handling/assembly equipment	X (assembly)	X
LCD filling material	X	
LCD filling tools	X	
Surface mounting (of chips) tools	X	
Completed display test tools	X	
Surface particle detection tools	X	
Completed display test tools	X	
Surface particle detection tools	X	
Thin film process control tools	X	
CD measuring/microscope stages	X	

Source: SEMI

SEMICONDUCTOR EQUIPMENT
AND
MATERIALS INTERNATIONAL

A White Paper
June 1989

Building An Equipment and Materials Infrastructure for High Resolution Video Manufacturing

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TABLE OF CONTENTS

Executive Summary i

Introduction: The HRV Challenge 1

A. General 1

B. The Role of the U.S. SEM Industry 2

C. Objective of the White Paper 3

Building an HRV Manufacturing Infrastructure 5

Leveraging the U.S. SEM Industry 9

A. Critical Components 9

  1. Integrated Circuits 9

  2. Displays 10

B. The U.S. SEM Industry 15

Steps Needed 22

A. Creation of a Domestic Customer Base 23

B. Increased Funding for Research and Development . . 24

C. Improved Intellectual Property Protection 27

D. Tax Incentives 30

E. Government Policies/Legal Restraints 31

U.S. Government Role 35

EXECUTIVE SUMMARY

High resolution video (HRV), including high definition television (HDTV) and other forms of advanced graphics, is predicted by many to be the critical technology that drives the electronics industry in the 1990s. It will provide not only advanced television and graphics display capabilities that will be useful in military, commercial, and consumer applications, but will also provide a stimulus for a number of key industries, including semiconductors, semiconductor equipment and materials, computers, telecommunications and broadcasting.

It is expected that the consumer market will eventually demand vast quantities of HRV devices for entertainment, computing and transferring information. HRV devices in turn will use a substantial amount of electronic components, especially integrated circuits and flat panel displays. The volume of demand for these devices and components will have a dominating impact on the electronics industry -- on its ability to generate internal funds and on its ability to manufacture on a large scale. It is in manufacturing of HRV-related components that the semiconductor equipment and materials (SEM) industry can make a decisive contribution, and where the industry has a major stake.

The United States is well behind Europe and Japan in investing in HRV manufacturing technology. Further, few U.S. firms have indicated a willingness to enter the HRV market. Nevertheless, HRV manufacturing technology is available in the United States or attainable within a reasonable time period. The real challenge is to create a domestic industry that can develop and manufacture HRV products so as to be competitive in the U.S. and world markets.

Building an HRV Manufacturing Infrastructure

Semiconductor Equipment and Materials International (SEMI) believes that a critical element in establishing this new industry is the development of an infrastructure for the production of the principal components -- flat panel displays and integrated memory and logic circuits -- for HRV displays and receivers. Manufacturing equipment and materials must be developed that will enable a U.S. HRV industry to procure these components domestically in quantities and at prices that are competitive with those available to non-domestic HRV makers.

Immediate action is needed to develop this manufacturing infrastructure, because manufacturing technology must be integrated into product design at an early stage to achieve low cost, high yield production. Other competitors in the HRV market, primarily the Japanese, are already engaged in building their infrastructure. A reliable SEM infrastructure that participates actively in the development of HRV devices can provide a substantial competitive advantage to the United States.

Leveraging the U.S. SEM Industry

The processes used to manufacture critical HRV components is similar to the processes used to manufacture semiconductors. Thus, the United States can leverage the technology employed in the semiconductor industry to develop an infrastructure to support an HRV manufacturing industry.

The United States currently possesses a SEM industry that is highly competitive in a number of technologies that can be adapted to produce the critical components needed for HRV. Firms in this industry are heavily engaged in research and development efforts, and could be a ready source of expertise for developing new manufacturing processes to lower costs and increase yields for HRV makers. Indeed, a limited number of U.S. SEM companies are already engaged in the development of equipment and materials for production of HRV components, although the primary market for their products is now in Asia.

While the U.S. SEM industry is heavily committed to R&D, this R&D is focussed primarily on maintaining U.S. competitiveness in the semiconductor market. The risks of moving into a new HRV market are substantial, particularly since the main users of HRV-related products are now located outside the United States, where U.S. SEM firms already face tough competition. Further, the capital resources of SEM firms are limited; most are small companies that finance their R&D budgets out of current revenues and thus have few resources to call upon for additional investments in HRV research and development. The availability of capital to these firms must be increased if they are to undertake substantial R&D in HRV.

Steps Needed

A number of steps are needed to enable the SEM industry to make a substantial investment in HRV.

First, a domestic market for HRV equipment and materials must be created through establishment of a number of viable U.S. entities that will procure equipment and materials for use in manufacturing components for HRV devices. Currently, the only significant HRV component makers are located in Japan and Europe.

Second, additional R&D capital must be made available to the SEM industry to fund the adaptation of existing semiconductor manufacturing technology to HRV production applications. SEMI estimates that adaptation of its technology to HRV specifications will require HRV-related segments of the industry to increase their R&D expenditures by $100 million to $120 million per year for five years. New government and private financial support will be needed to stimulate and supplement these increased R&D outlays.

Third, SEM firms must be able to protect intellectual property developed in cooperative HRV projects with government and/or industry. Most importantly, because market share has proven to be critical to the continued viability of the SEM industry, R&D funding cannot be premised upon any compromise of SEM firms' rights to market their products, either in the United States or in foreign markets.

Fourth, a more stable investment environment must be created. For example, tax incentives for R&D investments must be strengthened. Given the substantial R&D expenditures that will be required, the existing R&D tax credit must be made permanent, and other measures such as a reduced capital gains tax, shorter depreciation rates and an investment tax credit should be considered.

Fifth, government policies and legal constraints that can inhibit the emergence of an HRV industry need to be revised. In particular, antitrust policies and procedures to monitor and offset unfair trade practices should be streamlined to ensure that an emerging HRV industry has an opportunity to survive in the international market.

U.S. Government Role

Any HRV initiative should be industry led. As suggested by other industry associations, the role of the U.S. government in an HRV initiative should be to provide an environment that will allow U.S. industry an opportunity to compete in the production of HRV equipment. For the SEM industry, in addition to the above mentioned steps, this should include government measures to facilitate cooperation between HRV manufacturers and SEM suppliers in the development of appropriate manufacturing technologies. Only through the direct involvement of the U.S. manufacturing base can a viable HRV industry emerge in the United States.

Most importantly, the U.S. government should make a clear commitment to developing a U.S. HRV industry. Current industry reluctance to enter the HRV market stems primarily from the belief that non-domestic competitors, strengthened by vertically integrated production, low cost capital, and strong government support may possess insurmountable advantages in the HRV market. A credible U.S. government commitment will go far toward persuading U.S. industry and capital markets to make the investments needed to enter the HRV market.

Introduction: The HRV Challenge

A. General

High resolution video (HRV), including high definition television (HDTV),* has emerged as the strategic electronics technology for the 1990s. It will have momentous consequences for the electronics industry, directly affecting semiconductors, computers, telecommunications and consumer electronics. As one analyst put it:

> The world is poised on the threshold of a revolution in electronics in HDTV, which has enormous capability to affect most electronic industry segments. There are chilling implications for U.S. non-participation. The end reward for those who design, manufacture and sell to the HDTV market is dominance of computers and telecommunications.[1]

HRV is expected to produce a whole variety of technological benefits in defense electronics, such as command, communications and control equipment, intelligence analysis, and aircraft cockpit capabilities, and in civilian applications, such as television broadcasting, medical equipment, printing, electronic design, video program production, factory automation, publishing, and banking. HRV also offers an opportunity for U.S. industry to reenter the high volume consumer electronics market, which has been dominated by Japan over the past 15 years. The benefits of such reentry could be enormous. Analysts have pointed out that

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* The term "high resolution video," as used in this White Paper, addresses both high definition television, which is essentially a consumer electronics product, and high resolution computer graphics, which has consumer, business and engineering applications. Although different, both products will require the same components and should be considered together.

Japan's success in high volume consumer electronics (e.g. video cassette recorders, televisions) has supported Japan's expansion into other segments of the electronics industry. Most significantly, the revenues that sales of consumer products generate have helped finance and subsidize research into advanced electronics technologies, thereby keeping Japan's entire electronics industry state-of-the-art. Many predict similar benefits for the United States electronics industry should it use this opportunity to reestablish a major presence in the consumer electronics market.

B. The Role of the U.S. SEM Industry

The U.S. semiconductor equipment and materials (SEM) industry will be critically important to the success of any U.S. effort to produce HRV devices. Because of the technological similarity between equipment and materials requirements of the semiconductor industry and the requirements of manufacturing key HRV components, U.S. SEM firms offer a ready source of technological expertise that could be adapted to create equipment and materials for the manufacture of these components. At present, however, only a few companies in the SEM industry are investing in equipment and materials for HRV (primarily for the Japanese market) and few domestic customers for HRV-related SEM products have emerged. Absent an immediate effort to encourage more SEM firms to invest in HRV, it can be expected that Japanese and European companies will have little difficulty in securing a substantial, if not insurmountable, lead over the United States in the manufacture of these components and, as a consequence, in the production of HRV-related devices (e.g., HDTV receivers and HRV graphics displays).

The U.S. SEM industry has a major stake in participating in HRV. An HRV manufacturing industry would offer SEM firms an opportunity to diversify their domestic customer base, which now is limited to the declining U.S. semiconductor industry, and to help reduce the U.S. SEM industry's growing reliance on foreign markets. A strong domestic customer base for SEM HRV manufacturing products could also help reverse the U.S. SEM industry's decline in certain key segments and reinvigorate other segments in which the industry continues to maintain its market share. It would also present new possibilities for developing technology that could have benefits in a number of applications beyond HRV, including the manufacture of semiconductors, telecommunications products and computers.

C. Objective of the White Paper

Semiconductor Equipment and Materials International (SEMI) has prepared this White Paper to describe the role that the U.S. SEM industry could play in an HRV manufacturing industry. Among the issues considered in this paper: (1) the importance of a strong SEM supplier base for success in manufacturing commodity electronics products; (2) factors affecting the U.S. industry's ability to act as a possible supplier for HRV; (3) the steps that would be needed to bring SEM firms into the HRV industry; and (4) the proper role for the U.S. government in any effort to develop an HRV manufacturing industry.

In general, this White Paper argues that a coordinated industry-government partnership can help promote and facilitate the creation of an HRV industry. Of particular importance will be government measures to ensure that new capital is made available for investments in the development of equipment and materials for HRV manufacturing and to protect the value of these investments should they result in commercially valuable products. Beyond specific measures, however, the U.S. government must make a strong commitment to ensure an HRV industry can succeed. Absent such a commitment, it is unlikely that firms will be attracted to this new, but risky venture.

Building an HRV Manufacturing Infrastructure

The HRV market is not expected to become profitable until the 1990s. However, to secure a share of that market, it is important that U.S. firms begin now to create an infrastructure for the manufacture of critical components for HRV devices. Past experience in the consumer television market shows that, even if U.S. manufacturers have the most advanced technology, U.S. firms cannot survive if the tools and materials are not there to make reliable products and components at sufficiently low cost to be price competitive.[2] Thus, the challenge in the HRV market will not be merely developing the technology to manufacture HRV devices, but also adapting and perfecting this technology into efficient manufacturing processes capable of high yields at low cost.

Japanese consumer electronics companies have proven adept at developing these efficient manufacturing processes. While Japan's success has been attributed to a variety of factors, including the low cost of capital, government support of the electronics industry and economies of scale, one of the factors most often cited is the vertically integrated nature of Japan's major electronics manufacturers.[3] Each large manufacturer has suppliers that design their products with the specific needs of the company in mind, and that are involved at an early stage in the product development process. Further, because the major electronics manufacturers have significant capital resources available to them, they are able to fund major research efforts by their suppliers to develop new components, equipment and materials that they will need for their products in the future.

The close working relationship between Japanese manufacturers and suppliers has been cited as a key factor in Japan's success in the television industry. In the 1970's, the Japanese television industry was able to use this relationship to improve the quality and efficiency of television fabrication lines and thereby reduce TV prices.[4] Many of these same Japanese companies will be major players in the HRV market, and are already investing heavily in HRV production technology.** Similarly, the European companies that are expected to be HRV makers (e.g., Phillips) are also large vertically integrated entities.

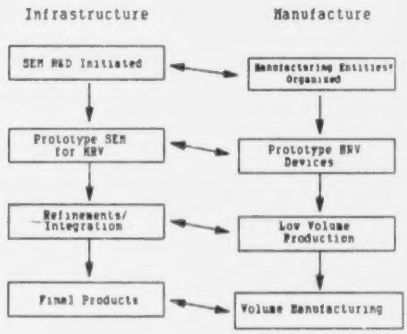
By contrast, a critical weakness in the United States is the failure of U.S. manufacturers to work closely with their suppliers in the conduct of research and development activities. While many U.S. suppliers do expend considerable resources in order to stay current with their customers' needs, there is no structural mechanism for ensuring that accurate and timely information about the customers' needs reaches these suppliers. Nor is it common for suppliers to be included early in U.S.

** For example, the American Electronics Association (AEA) reports that the Japanese Ministry of International Trade and Industry (MITI) has joined with 12 Japanese companies (including Casio, Sharp, Hitachi, NEC, Sanyo and Seiko) to invest $74 million in developing a 40-inch flat panel liquid crystal color display for commercial sale by 1994. AEA, High Definition Television (HDTV): Economic Analysis of Impact (Nov. 1988) (A Working Document prepared by AEA's ATV Task Force Economic Impact Team).

manufacturers' product design and development efforts. As a result, it is difficult for U.S. suppliers to provide U.S. manufacturers with the equipment and materials they need to achieve efficient production. This separation of suppliers and manufacturers has been a particular drawback in the U.S. semiconductor industry, which the U.S. government and industry has only recently begun to address.[5]

If the United States is to build a successful HRV industry, it is clear that manufacturers and suppliers must work together to develop the efficient manufacturing lines --including fabrication, assembly and testing -- that will ensure U.S. equipment is competitive on the world market. As Figure 1 illustrates (page 8), SEMI believes that SEM firms and SEM research will play a key role in the process of building this HRV manufacturing industry.

Figure 1


Infrastructure
Manufacture
SEM R&D Initiated
Manufacturing Entities*
Organized
Prototype SEM
for HRV
Prototype HRV
Devices
Refinements/
Integration
Low Volume
Production
Final Products
Volume Manufacturing

BUILDING AN HRV INDUSTRY

* Individual Firms, Joint Ventures, Consortia, etc

Source SEMI

At each step of the process, SEM participation will be essential if efficient volume manufacturing is ultimately to be achieved. Potential HRV device manufacturers need to realize this and ensure that SEM firms participate closely in any effort to undertake HRV manufacturing. Further, the U.S. government can assist in this process by taking steps to encourage U.S. SEM industry participation in all HRV manufacturing efforts. (*See* pages 22-34 for a discussion of the specific steps needed.)

Leveraging the U.S. SEM Industry

The United States' success in establishing an HRV industry will depend largely on its ability to produce the electronic components needed to make HRV devices.*** Two components are expected to be critical: integrated circuits and high resolution video displays.[6] As described below, much of the technology for the production of these components will come from the U.S. SEM industry. Indeed, many of the elements of the technology already exist and can be adapted to HRV production. However, adaptation of this technology will require a major commitment of resources and, most importantly, the emergence of companies or other entities that are interested in investing in this technology. Neither has yet occurred.

A. Critical Components

1. Integrated Circuits

HRV devices will require a number of integrated circuits (ICs), including logic and memory devices, to run the sophisticated graphics features that will be incorporated in the devices. Of these ICs, the major component will be dynamic random access memories (DRAMs). While the U.S. SEM industry has the technology needed to produce DRAMs, only a few U.S.

*** For these purposes, the term "HRV device" is intended to include HDTV receivers and high resolution graphics displays. These devices will be the end products that will be sold on the consumer electronics market and will generate the greatest revenue. Of course, other types of HRV equipment will also need to be developed, e.g., equipment for television programming production. This type of equipment is not considered here.

semiconductor companies are currently engaged in DRAM production. Most of this is "captive" production that is devoted solely to the needs of major computer and telecommunications firms, and would likely not be available to a U.S. industry manufacturing HRV devices.

Today, almost all DRAMs available on the commodity IC market are produced by Japanese companies. Reestablishing new DRAM manufacturing lines in the United States that are capable of producing DRAMs at costs and yields competitive with those now being achieved by non-domestic DRAM producers will require a substantial amount of new R&D and investment, as well as close cooperation between any new U.S. DRAM makers and their SEM suppliers.

2. Displays

Approximately 50% of the cost of HRV equipment will be determined by the cost of producing the display.[7] It can be expected that cathode ray tubes (CRTs) will be the display technology used in the first high resolution receivers and computer monitors. Ultimately, however, CRT technology is not likely to be sufficiently flexible to be a satisfactory solution for HRV devices. For example, a CRT used in a color television employs an electron gun that directs beams of electrons through a shadow mask onto color phosphors on the display screen.[8] Given the need to place the gun at a distance from the screen, the CRT is rather bulky and heavy, particularly as the screen size increases.[9]

Adoption of digital displays technologies could permit an increase in the size of the screen without the increase in cabinet bulk and weight, and would also allow for a wider range of features than are permitted by CRTs. Rather than using electron beams, these "flat panel" technologies display images by turning on or off individual picture elements (pixels) on the display screen. Such displays have already been produced for the military and for other low-volume, high cost applications.[10] While the resolution of many of these displays is not yet on par with color televisions, companies making the displays are moving rapidly to overcome this problem. Further, most Japanese electronics companies with an interest in the HRV market -- most notably, Matsushita, Mitsubishi, Sharp, Hitachi, Toshiba, Sanyo, and Seiko Epson -- are investing heavily in this newer technology.[11]

There are at least three types of flat panel display technologies under development or in production today: electroluminescence, liquid crystal (LCD) and gas plasma. Liquid crystal displays appear to hold out particular promise for HRV applications, and in particular "active matrix" liquid crystal displays (AMLCD). AMLCDs use a grid of individual thin-film transistors deposited on a piece of glass to control individual pixels.[12] Each transistor is dedicated to a single pixel, and turns the pixel on or off, depending upon the image to be produced. The greater the number of pixels, the finer the resolution.

The process of manufacturing an AMLCD is strikingly similar to the process of making an integrated circuit, and involves essentially the same type of production techniques. There are important differences, however. First, the glass substrate used to make the display is obviously much larger than the typical silicon IC substrate, which makes it difficult to use existing lithography equipment.[13] A few U.S. companies have developed equipment that can handle glass substrates up to one-half (.5) square meter. Beyond that size, however, totally new lithographic processes may have to be developed.

Second, the lithographic requirements of making AMCLDs are quite demanding. The glass substrate cannot withstand the high temperatures that are common in IC manufacture, yet the line width of some parts of the matrix may need to be as fine as two microns. As one researcher has put it, "[a]n active matrix display is like a megabit DRAM built on a low cost glass substrate."[14]

Finally, while existing equipment can be used or modified to produce AMLCDs, further work is needed to develop fabrication and assembly processes that will allow AMLCDs to be produced at prices that will make them competitive as a commodity electronics product.[15] This will require a substantial investments of resources, and is not likely to yield any profits for a number of years. The long-term nature of this research poses a particular problem for U.S. SEM makers, because they have few additional resources for development of these products. Further, the market for AMLCD production equipment and materials is almost entirely in Japan at present. Given the close ties between Japanese SEM companies and Japanese AMLCD makers, it may be difficult for U.S. SEM makers to establish a market in Japan among AMLCD makers sufficiently strong to justify substantial investments in AMLCD-related equipment and materials.

Table 1 provides a breakout of the major requirements for AMLCD production, and indicates which requirements involve SEM technologies:

Table 1

AMLCD Production Requirements

Requirement	SEM	non-SEM
Glass substrates	X	
Backlighting source		X
Filters/polarizers		X
Substrate clean, dry equipment	X	
Photoresist material	X	
Photoresist coating equipment	X	
Photoresist pre-bake equipment	X	
Photolithography exposure tools	X	
Photoresist development equipment	X	
Photoresist hard-bake equipment	X	
Thin film etching equipment	X	
Thin film evaporation/sputtering tools	X	
Chemical vapor deposition (CVD) equipment	X	
Laser annealing/materials conversion tools	X	
Metals/gases for sputtering/CVD	X	
Materials handling equipment (whole line)	X	
Inspection tools	X	
In-process circuit test tools	X	
Repair tools	X	
Assembly tools	X	
Automatic handling/assembly equipment	X (assembly)	X
LCD filling material	X	
LCD filling tools	X	
Surface mounting (of chips) tools	X	
Completed display test tools	X	
Surface particle detection tools	X	
Completed display test tools	X	
Surface particle detection tools	X	
Thin film process control tools	X	
CD measuring/microscope stages	X	

Source: SEMI

As noted above, a few U.S. SEM firms already have products that meet one or more of these requirements. For example, the major supplier of the special type of glass used for AMLCD substrates is a U.S. company. In addition, several U.S. firms specializing in the production of semiconductor lithography equipment are offering products that could be used for AMLCD production. Further, many of the materials, gases and general supplies used in IC production can also be applied to the production of HRV components without significant modification.

Products for a substantial number of AMLCD production requirements still need to be developed, however, including:

- large area deposition (sputtering/chemical vapor deposition) equipment
- equipment for wide-area lithography (more than one-half square meter)
- etch equipment
- in-line photoresist processing equipment
- automatic test/repair equipment
- automatic assembly/handling equipment

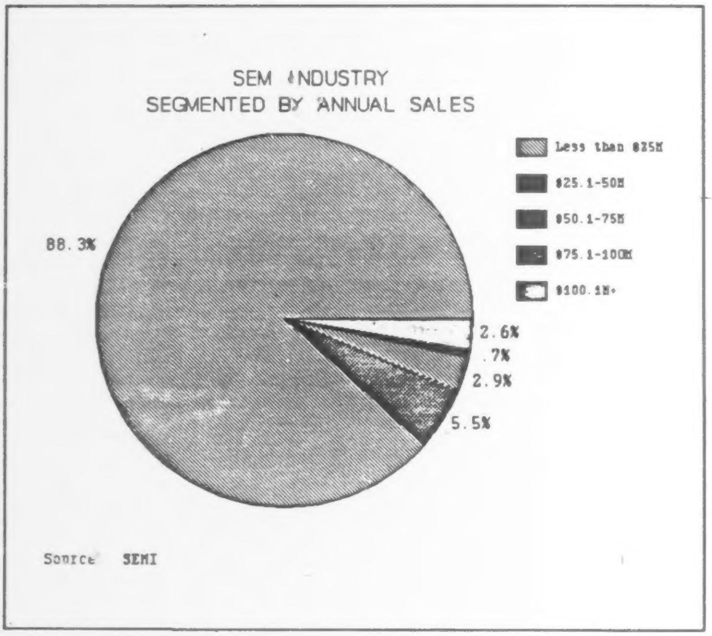
These areas will require major new R&D investments in order to adapt existing technology to large-scale AMLCD production.[16] Further, to make these new technologies pay off in commercial production, they all must be integrated in manufacturing processes that will permit efficient and low cost production. Thus, not only must new products be developed, each must be developed in close coordination with other suppliers and companies that will use this equipment, to maximize the efficiency of the entire manufacturing process.[17]

B. The U.S. SEM Industry

As Table 1 suggests the primary source of technology for producing integrated circuits and flat panel displays for HRV manufacturing will be the SEM industry. Despite a recent decline in its share of the world market, the U.S. SEM industry remains state-of-the-art in many of the critical technologies critical to the manufacture of HRV components. Given appropriate support, the United States can leverage this industry into a domestic supplier base for an HRV manufacturing industry.

While a potential asset for any HRV effort, the U.S. SEM industry is not well-positioned to invest in developing equipment and materials for HRV production. The typical U.S. SEM firm is a small, independent manufacturer with annual sales of less than $25 million. (See Figure 2 below).

Figure 2



Source SEMI

It is generally a highly specialized company, focussing on the manufacture of a particular type or line of equipment or materials for selected steps in the semiconductor fabrication process. Few U.S. SEM firms are able to dominate large segments of the market or rely on an established installed base. The rapid pace of product obsolescence demands that these firms devote a substantial amount of their resources to research and development (R&D) in order to maintain market position.[15] Indeed, SEMI estimates that a typical SEM firm devotes 10% to 14% of annual revenues to ongoing R&D, and that the industry as a whole spends $600 million on R&D annually.

Non-domestic competition has eroded the U.S. industry's once-commanding lead in the world market. The changing position of the U.S. industry can best be judged from Table 2 (page 18), which compares the top ten SEM firms in the world in 1982 and 1988. In 1982, three of the top five firms, including the top two, were American. Today, only two of the top five are U.S.-owned, and the top three firms are Japanese.

Table 2

Top Ten Semiconductor Equipment Manufacturers Worldwide Sales ($Millions)

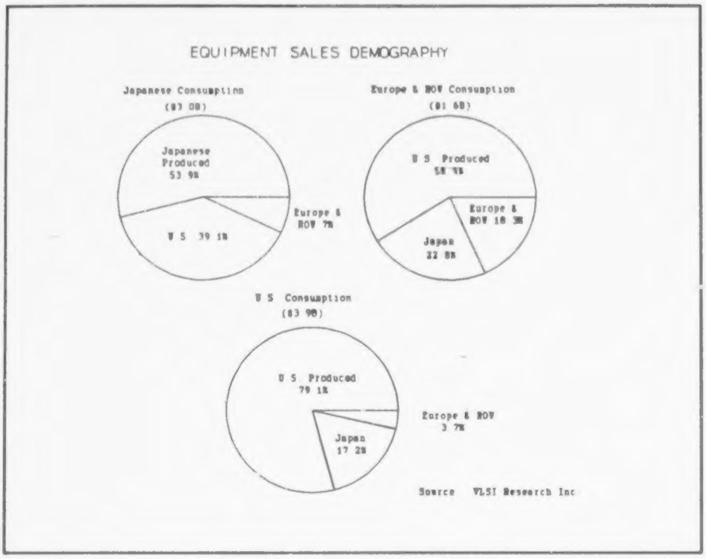
1982		1988	
U.S. - Perkin-Elmer	$162.1	Japan - Nikon	$520.7
U.S. - Varian	99.5	Japan - Tokyo Electron (TEL)	508.3
France - Schlumberger	96.4	Japan - Advantest	384.9
Japan - Takeda Riken (Advantest)	83.8	U.S. - Applied Materials	381.7
U.S. - Applied Materials	83.4	U.S. - General Signal	375.2
U.S. - Eaton	79.9	Japan - Canon	289.7
U.S. - Teradyne	78.7	U.S. - Varian	210.9
Japan - Canon	77.7	U.S. - Perkin-Elmer	205.2
U.S. - General Signal	76.9	U.S. - Teradyne	189.7
Japan - Nikon	57.7	U.S. - LTX	179.5
Source: Electronic Business, May 1984		Source: VLSI Research Inc., March 1989	

In addition, Perkin-Elmer, one of the top ten in both lists, has recently announced that it will sell its semiconductor manufacturing equipment business.[19]

The decline of the U.S. industry can be traced in large part to the problems experienced by the U.S. semiconductor industry in recent years. The U.S. SEM industry developed as spin-off of the domestic semiconductor industry and was almost exclusively devoted to serving its requirements throughout most of the 1970s. When the semiconductor industry began to contract in the early 1980s, the U.S. SEM industry found itself faced with a shrinking customer base, which placed many SEM firms in a difficult position.

The U.S. SEM industry responded to the decline in its domestic market by aggressively pursuing non-domestic customers. As a result, while the industry has lost some of its dominant position in the world, it has retained a sizeable share of the world market and, in fact, has modestly improved its position in foreign markets in the last two years. It is estimated that, in 1988, the U.S. SEM industry accounted for 79.1% of equipment and materials sales in the United States, 39.1% of sales in Japan and 58.9% of sales in Europe and the rest of the world. (See Figure 3 on page 20.)

Figure 3



Source VLSI Research Inc

These figures represent an increase over 1987, when the figures were 77%, 34.8% and 58.7%, respectively. These increases compare favorably with the performance of other electronics industry segments, which have experienced losses or no gains in Japan and other markets in recent years.

Despite the success, it is clear that the U.S. SEM industry is experiencing a period of consolidation and restructuring. The industry still maintains a lead in certain product segments, such as sub-micron lithography, but it is being challenged on a number of fronts by non-domestic competitors (See Figure 4 below).

Figure 4

STATUS AND TRENDS OF U.S. SEMICONDUCTOR EQUIPMENT AND MATERIALS TECHNOLOGY RELATIVE TO JAPAN

	JAPAN LEAD	U.S.-JAPAN PARITY	U.S. LEAD
MATERIALS			
Silicon	◀		
Gallium Arsenide	◀		
PROCESSING EQUIPMENT			
Optical Lithography		◀	
E-beam Lithography			◀
X-ray Lithography		◀	
Ion Implantation Technology			
Chemical Vapor Deposition		●	
Deposition, Diffusion, Other		●	
Energy-Assisted Processing	◀		
Assembly		●	
Packaging	◀		
Test	◀		
CAE		●	
CAM		◀	

● U.S. Position Maintaining
◀ U.S. Position Declining

Source: Interagency Working Group on Semiconductor Technology

Thus, while the emergence of an HRV industry could help reinvigorate the U.S. SEM industry, it is clear that U.S. SEM makers can ill-afford to divert resources now focussed on maintaining their competitiveness in the semiconductor industry to R&D for HRV. Additional steps will be needed to enable these firms to diversify into HRV.

Steps Needed

Given the reluctance of individual firms to invest in HRV, a coordinated industry-government HRV strategy may be needed to mobilize U.S. industry to participate in building this new industry. Such a strategy would likely have to address a number of areas, including transmission and production standards, foreign trade issues, antitrust restrictions, and appropriate marketing and distribution strategies. Many of these areas extend far beyond the interests of the SEM industry, and are best addressed by the industries they directly affect.

From the SEM industry's perspective, however, it is possible to identify a number of specific steps that must be taken for the industry to make a substantial commitment to HRV. These steps include:

- establishment of a base of domestic manufacturers committed to producing HRV devices
- financial support for investment by SEM firms in HRV technology
- specific guarantees that any intellectual property developed by SEM firms jointly with government or industry for HRV applications will be protected and SEM products made with this technology can be sold by SEM firms in foreign markets
- tax incentives for R&D expenditures by SEM firms and for investment in SEM products by customers
- modification of government policies and legal restraints that inhibit SEM industry cooperation with users and that impede the enforcement of U.S. laws against unfair trade practices

Each step is discussed below.

A. Creation of a Domestic Customer Base

U.S. SEM firms will not invest in equipment and materials for the manufacture of HRV components unless it appears there will be a domestic industry to procure these products. While U.S. SEM firms have been successful in foreign markets, the close ties with customers needed for SEM firms to be competitive are not easy to establish in these markets. Therefore, it is unlikely that the U.S. SEM industry will devote a substantial amount of its resources to developing materials and equipment for production of HRV components, when the lack of domestic customers places it at a competitive disadvantage in the world market.

The domestic demand from one or two isolated start-up companies or manufacturing consortia is likely to be insufficient. Instead, SEMI members estimate that they will ultimately need at least four and preferably ten or more domestic HRV components manufacturers for a U.S. HRV equipment and materials market to be profitable.

For these purposes, it is less relevant whether the owners of domestic HRV manufacturing operations are non-domestic or American than whether the investment in manufacturing contributes to the creation of a viable infrastructure for HRV production. For example, the United States will reap few benefits if manufacturing operations established in the United States -- whether foreign- or American-owned -- involve only assembly of foreign-made components. Instead, such operations must include component production, requiring the procurement of a substantial amount of U.S. SEM products.

Domestic manufacturing operations should serve not simply as a market to which U.S. SEM firms can sell, but also as the catalyst for the development of commercially useful production technology. Just as has happened in the Japanese semiconductor industry, the technical exchange and cooperation between U.S. SEM firms and U.S. HRV manufacturing entities can help generate development of advanced technology that will ensure the equipment and materials industry remains state-of-the-art in both HRV and other component manufacturing segments.

B. Increased Funding for Research and Development

A substantial amount of investment will be needed to fund the development of equipment and materials for HRV applications. The cumulative annual R&D budget of the entire U.S. SEM industry -- estimated at $500 million to $600 million -- is already substantial. SEMI estimates that SEM firms with product lines related to HRV will need to increase their annual R&D spending a total of $100 million to $120 million to finance the adaptation of existing technology to HRV applications. Further, this increased R&D funding would have to be maintained for a period of at least 5 years. Moreover, this estimate applies only to the funding needed to adapt existing technology to HRV applications; substantial additional investment beyond this amount would be needed to support the development of advanced equipment, e.g., new lithographic techniques for production of AMLCD panels with a size in excess of one-half square meter.

Initially, funding for much of this investment might have to come from government sources. The costs of establishing an entire industry based upon generally unproven technologies will obviously be substantial. For the U.S. SEM industry, which consists primarily of smaller firms that together already devote a substantial portion of their resources to R&D, government assistance will be particularly critical.**** What U.S. SEM companies face now are the prospects of funding substantial "sunk costs" -- R&D, equipment acquisitions, retooling and so forth -- without any hope of achieving a return on their investment for a number of years. Yet, despite the risks, these investments could yield enormous benefits in the long run, not only for the SEM industry, but also for the U.S. electronics industry and, ultimately, the U.S. economy. To persuade SEM companies to run the risks, an initial government investment in HRV-related SEM technologies will be needed.

The types of funding provided may vary. For SEM firms interested in developing technology for HRV, funding could involve merely "seed money" or impact grants that permit a

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**** To date, the U.S. government has agreed to provide modest support for HRV R&D in the form of a $30 million program announced by the Defense Advanced Research Projects Agency (DARPA) in late 1988. Ten SEM firms responded to the DARPA announcement with proposals for HRV projects, although it is generally agreed within the industry that $30 million will be insufficient to finance all the R&D needed to develop equipment and materials for the manufacture of HRV components.

substantial number of firms to undertake new R&D efforts, in addition to the R&D they are already conducting. In other cases -- for example, where smaller companies are involved or the R&D is particularly risky -- more substantial grants or loans could be required.

Aside from R&D support to SEM firms, U.S. government financial assistance will also be needed to assist joint ventures or other entities formed to manufacture HRV-related devices and components. These companies will need substantial amounts of capital to procure the equipment and materials necessary to begin production. To assist these entities, the U.S. government may need to fund a substantial part of the costs of investing in plant and supplies, using tax benefits, grants, loans or loan guarantees.

The initial cost to the U.S. government of funding an HRV effort may be substantial. Over the long run, however, it can be expected that, as domestic component manufacturers emerge, private funding will increase. Thus, while overall investment requirements are large, the outlay required from the U.S. government may be relatively modest.

Aside from directly funding R&D and manufacturing, the U.S. government could indirectly support these activities by making HRV-related efforts a priority in government procurement and research and development programs. For example, preference could be given to procurements that help further the development of HRV components and devices. In addition, university researchers funded by the U.S. government could be encouraged to undertake projects that would help the HRV effort. New research efforts specifically targeted to equipment and materials manufacturers would also be useful to promote the development of HRV-related technology.

Investment in research and development must begin immediately. With the Japanese planning to introduce the first commercial HDTV products in the early 1990s, and the Europeans efforts well under way, the United States must turn its attention now to developing products for this new market. Current government-sponsored R&D efforts, such as the $30 million research program to be funded by the Defense Advanced Projects Research Agency (DARPA), are simply too small to meet this challenge, and, while welcome, do not address the commercial obstacles (e.g., investment risk, unfair trade problems, intellectual property concerns) now blocking the development of a commercially-viable manufacturing industry.

C. Improved Intellectual Property Protection

Intellectual property rights are a major concern for the SEM industry. SEM firms depend upon the ability to exploit the value of their technology in order to recoup the substantial investments they make in research and development. Intellectual property rights can be threatened in a number of ways, including (a) requirements for technology transfer as a prerequisite for participation in joint ventures and consortia; (b) legal limitations on the ability to exploit technology in foreign markets; (c) foreign laws or procedures that make it difficult or impossible to secure legal protection for intellectual property; (d) procedures for intellectual property protection that are either too unwieldy or costly for small SEM firms to utilize effectively; and (e) the difficulty of protecting rights in proprietary processes, as opposed to products, that are pirated and used in foreign countries to make competing products.

Respect for intellectual property rights will be a critical issue for SEM companies if consortia or joint ventures are to play a key role in a U.S. HRV strategy. A small SEM firm partnered with a larger electronics manufacturer (or manufacturers) and/or with the government in a joint HRV manufacturing effort could be at a significant disadvantage in resisting attempts to transfer its technology to other sources or to place restrictions on the use of its technology in other, competing applications. Of particular concern will be government-imposed limitations on selling products developed in such joint ventures in export markets such as Japan, where U.S. firms have a substantial presence. The experience of the SEM industry in the early 1980s has proven that it is critical for SEM firms to maintain a significant share of the world market if they are to survive downturns in particular geographic segments of the market. Thus, there should be no restrictions on the use of this technology to generate revenues that can help fund further R&D.

Protection of U.S.-developed intellectual property under foreign laws is also of concern to SEM firms. SEMI welcomes recent legislation in the United States that places a new priority on intellectual property protection in international trade. SEMI also supports the efforts of the United States and other Western governments to establish an international regime for intellectual property protection within the framework of the General Agreement on Tariffs and Trade (GATT). Recognizing that the success of GATT negotiations is uncertain, however, SEMI believes the United States should also pursue bilateral negotiations to improve protections afforded by the United States' major trading partners.

SEMI believes that more needs to be done to make intellectual property rights easier for individual companies to enforce. Many of the intellectual property protections now available to U.S. companies are difficult for small firms to use and typically require the expenditure of a substantial amount of resources to pay the costs of defending these rights in legal or administrative proceedings. At a minimum, procedures should be adopted to ensure expeditious, low-cost resolution of intellectual property disputes. Such reforms are needed to protect smaller SEM firms engaged in research and development from losing the benefits of their investment.

D. Tax Incentives

Tax incentives represent one of the most effective ways of enticing U.S. firms to invest in research and development. Currently, U.S. tax law provides a limited number of benefits for research and development. For example, Section 41 of the Internal Revenue Code provides a credit against Federal income tax for expenses incurred in certain research activities and for payments made to certain qualifying organizations for basic research. The credit is limited to twenty percent (20%) of the amount by which these expenses and payments exceed the average R&D expenses and payments made over the three previous years. While useful as an incentive for U.S. firms, the credit is due to expire at the end of 1989.

The tax credit should be extended and made a permanent part of the Internal Revenue Code. Firms engaged in research for HRV purposes will need this credit to help offset the substantial up-front investments they will need to make in order to develop technology for HRV applications. Given the infancy of the HRV industry, it can be expected that research will yield little or no return for a number of years. Consequently, a tax credit can play an important role in giving firms involved in this research an interim financial return on their research investment.

Tax incentives to encourage HRV R&D need not be limited to merely extending the research tax credit, however. Consideration should also be given to expanding the scope of the tax credit to cover a broader range of activities, such as the development of products for the commercial market, and to removing limitations now imposed on deductions that can be taken for research and development expenses by firms that take advantage of the credit. Adjustments in the alternative minimum tax could be particularly beneficial to companies in the widely cyclical SEM industry.

It would also be useful to revise tax rules, such as depreciation rates and capital gains tax rates, that affect the investment decisions of HRV manufacturers. For example, the five-year time period currently used to calculate depreciation for semiconductor manufacturing equipment is simply not realistic, when compared with the actual useful life of such equipment in this highly competitive industry. Finally, consideration should be given to adoption of a limited investment tax credit for companies actively engaged in HRV manufacturing that invest in U.S. SEM products. Such a credit could help compensate these firms for the high risks they are undertaking in entering this new market.

E. Government Policies/Legal Restraints

One of the principal concerns of firms contemplating entry into the HRV market is the fact that, given the substantial lead that America's non-domestic competitors now have in the commercialization of HRV equipment, it is unlikely that any individual firm has the resources needed to obtain a substantial share of the HRV market. By contrast, the vertically integrated, better financed non-domestic companies that U.S. firms will face in the HRV market will be in a much better position to undertake manufacturing and secure substantial market share. Many believe it may be necessary for firms to work together in teams in which they pool resources and share risks, in order to catch up with these non-domestic competitors.

Teaming creates a number of problems for SEM firms. First, a team that includes large firms accounting for a substantial segment of the electronics market could be considered to be anti-competitive within the scope of the U.S. antitrust laws, thus subjecting participating U.S. SEM firms to liability for civil damages and criminal penalties. Second, teaming will make little sense if it does not afford SEM firms an opportunity to expand their customer base. SEM firms will be reluctant to participate if, after the necessary technology is developed, the users on the team choose to transfer their technology to, or purchase their equipment from, non-participating firms, particularly firms in overseas markets. Teaming should imply a long-term relationship between suppliers and users. Finally, a teaming arrangement should not detract from a SEM firm's ability to sell abroad, given the fact that the domestic market is not likely to be large enough to offer SEM firms an adequate return on their investment in developing the equipment.

A number of these concerns can be resolved in the terms of the agreements entered into by participants in each team. However, the antitrust problems may require modifications to U.S. law or the issuance of appropriate advance rulings by the U.S. Department of Justice. Further, protection of SEM firms' ability to market their products abroad may depend, not only upon private arrangements between team members, but also upon the application of export control policies that do not unnecessarily inhibit U.S. SEM firms from selling in overseas markets. This will be a particularly important concern where SEM firms are asked to participate in government-led teams.

In addition to these concerns, there is also a concern that the U.S. industry will not be able to compete against imported equipment and materials that are sold at unfairly low -- e.g., dumped or subsidized -- prices. In the past, U.S. unfair trade laws have not proven to be an effective deterrent to such practices because they are procedurally cumbersome, require a significant investment of resources for petitioners to invoke and typically do not achieve results until long after the damage to the U.S. industry has been done (indeed, injury generally is a prerequisite to the use of these remedies.) While the U.S. Congress has mandated a number of changes to U.S. trade laws that appear to require more active measures against unfair trade practices, application of these laws remains highly discretionary with the Executive branch.

A U.S. HRV industry will not succeed if dumping or export subsidization are allowed to go unchecked. At a minimum, procedures need to be implemented for monitoring imports and initiating investigations immediately once monitoring reveals evidence of unfair trade practices. Further, prosecuting these investigations should not require a substantial investment on the part of a U.S. firm to initiate, but rather should be handled by the U.S. government upon its own initiative and in accordance with an expedited timetable, consistent with the United States' GATT commitments. Relying upon the HRV industry to prosecute these types of cases will only divert resources needed for research and development.

U.S. GOVERNMENT ROLE

SEMI believes that industry, and not government, should lead the effort to create an HRV industry. Industry has the resources and creativity needed to make the effort succeed, and industry stands to gain the most from reentry into the HRV market. Further, it is likely that any government-led or -funded entity or consortium established to manufacture HRV equipment will not be sufficiently large to support meaningful investment by SEM firms in developing equipment and materials for an HRV industry. As noted above, SEM firms need a broad manufacturing infrastructure with sizeable equipment and materials requirements to make such investments worthwhile. Such an infrastructure will only develop through substantial private industry involvement.

While the U.S. government will not play the lead role, it must play an important and substantial role, particularly in the early stages, to stimulate serious interest and investment in HRV among U.S. firms and to create the environment needed for these firms to compete in the HRV market. It must be recognized that, at the present time, the risks of entering the HRV market are simply too great for many firms, particularly small SEM firms. Further, with only one domestic television manufacturer, the United States lacks the base of electronics companies that could be expected to invest in this market. Thus, governmental assistance is needed not simply to reduce risks, but also to persuade firms from other segments of the electronics industry (or from outside the electronics industry) to invest in developing the HRV manufacturing base.

The government can play a key role in bringing various parts of the electronics industry together. For example, early coordination between equipment and materials firms, on the one hand, and potential component manufacturers, on the other, will be extremely important if SEM firms are to meet users' needs. While relationships between suppliers and users can also be expected to develop through private ventures established by industry to pursue HRV manufacturing, the government can help bring the users and suppliers together by including representatives of SEM firms in advisory groups on HRV issues and by stressing the need for potential HRV manufacturers to work closely with their suppliers to develop the manufacturing base. Further, over-reliance on non-domestic suppliers should be discouraged, as this tends to subordinate U.S. manufacturers' needs to the needs of their non-domestic competitors, who often have special ties with their suppliers.

Obviously, there are numerous options available to the U.S. government, and it is not possible to identify all the steps that the government might take in order to ensure the success of a U.S. HRV industry. Moreover, while it is clear that government involvement is necessary, it is not clear how extensive this involvement will need to be. At this point, the most important contribution that the U.S. government can make is a firm and credible commitment to developing an HRV industry in the United

States. The reluctance of the U.S. electronics industry to enter into the HRV market -- which will surely be a dominant segment of the electronics market for the next several decades -- is based primarily upon the fear that non-domestic competitors may have insurmountable advantages, including unlimited supplies of low cost capital, guaranteed home market shares, the vertical integration of foreign manufacturing operations, and favorable domestic tax and investment policies. These advantages would not exist in a truly competitive market, but result largely from the strong support of foreign governments for developing their domestic HRV industries. In this environment, funds invested by U.S. industry may not be sufficient to offset these foreign advantages, as the history of the consumer electronics in the United States demonstrates.

A strong commitment by the United States to take whatever steps are needed to ensure the success of the HRV industry could help to reduce this risk substantially. Such a commitment must be based on a government consensus to seriously fund R&D, revise government policies to encourage cooperative action, encourage private investment and act quickly to offset unfair trade practices. In practice, such a commitment need not involve any more government support than has been provided in the past to other key industries, such as the semiconductor and aerospace industries, that the United States has viewed as an important part of its industrial base. However, by making a broad commitment, the U.S. government could give private industry and capital markets sufficient comfort to invest in this new industry. While there would be no guarantee that this investment would be profitable, and private industry would still bear much of the risks involved in commercializing HRV technology, investors could gain a crucial margin of confidence in making investment decisions and in undertaking efforts to enter a promising, but risky, new age technology market.

Notes

1. "AEA Study Says U.S. Needs HDTV", Electronic News, November 28, 1988, at 36 [hereafter referred to as "AEA Analysis"].

2. See Hart, The Consumer Electronics Industry in the United States: Its Decline and Future Revival, at 12-15, 17-18, 26-27. (Draft of October 1988) [hereafter referred to as "Hart"].

3. Stowsky, The Weakest Link: Semiconductor Production Equipment, Linkages, and the Limits to International Trade, at 38 (Berkeley Roundtable Working Paper, Aug. 1987) [hereafter referred to as "Stowsky"].

4. Hart, supra, at 27.

5. Stowsky, supra, at 24.

6. AEA Analysis, supra, at 4-4.

7. Schneider & Resor, "High-Volume Production of Large Full-Color Liquid-Crystal Displays", Information Display, February 1989, at 13 [hereafter referred to as "Schneider and Resor"].

8. Bursky, "Color Flat-Panel Displays Strut Their Stuff at SID," Electronic Design, April 28, 1988, at 22.

9. "High-Definition TV is Rallying a Digital Revolution," Business Week, Jan. 30, 1989, at 64, 65.

10. "Military Gets Active-Matrix LCD That Outshines a CRT Display," Electronics, October 1, 1987, at 90 [hereafter referred to as "Military AMLCD".]

11. "U.S. Component Suppliers Miss the Flat-Panel TV Show," Electronics Business, July 15, 1988, at 18.

12. Military AMLCD, supra, at 91.

13. Schneider and Resor, supra, at 8.

14. Firester, "Silicon Transistor Active Matrix Liquid Crystal Displays," Solid State Technology, December 1988, at 63, 67.

15. Ibid.

16. It is important to note that choosing whether to invest in lithography equipment for larger panel sizes poses a difficult choice for any U.S. HRV effort. Developing

lithography equipment to make displays larger than one-half square meter will require entirely new equipment and substantial research. However, if successful, the United States could "leapfrog" its competitors and seize a commanding share of this promising market, which will become increasingly important as high definition television technology advances. In addition, entirely new processes and techniques may be needed to produce lithography equipment capable of handling substrates larger than one-half square meter.

17. Stowsky, supra, at 39.

18. As the Commerce Department noted in its 1985 study of U.S. SEM industry competitiveness:

> In this technology-driven industry, a one to two-year hiatus in the conduct of research and development may mean the loss of a sizeable chunk of the market.

U.S. Dep't of Commerce, A Competitive Assessment of the U.S. Semiconductor Manufacturing Equipment Industry 81 (Mar. 1985).

19. "Top Chip Equipment Producer To Divest," Financial Times, April 22-23, 1989, at 12.

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